ARI Research Note 89-21

Education and Training Practices: 2010 and Beyond

Marshall J. Farr
Allen Corporation of America

and

Ray S. Perez
Army Research Institute

for

Logistics Training Technologies Technical Area
Robert J. Seidel, Chief

Training Research Laboratory
Jack H. Hiller, Director

May 1989

United States Army
Research Institute for the Behavioral and Social Sciences

Approved for the public release; distribution is unlimited

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

JON W. BLADES
COL, IN
Commanding

Technical review by

Douglas H. Macpherson

NOTICES

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS: - -
2a. SECURITY CLASSIFICATION AUTHORITY: n/a	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE: - -	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): ARI Research Note 89-21	5. MONITORING ORGANIZATION REPORT NUMBER(S): OPM 41-83 Work Order No. 41-121
6a. NAME OF PERFORMING ORGANIZATION: Allen Corporation of America; 6b. OFFICE SYMBOL (If applicable): - -	7a. NAME OF MONITORING ORGANIZATION: US Office of Personnel Management
6c. ADDRESS (City, State, and ZIP Code): 209 Madison Street, Alexandria, VA 22314	7b. ADDRESS (City, State, and ZIP Code): Office of Training & Development, P.O. Box 7230, Washington, D.C. 20044
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: US Army Research Institute; 8b. OFFICE SYMBOL (If applicable): PERI-II	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: OPM 41-83 Work Order No. 41-121
8c. ADDRESS (City, State, and ZIP Code): 5001 Eisenhower Avenue, Alexandria, VA 22333-5600	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. 6.27.85; PROJECT NO. A791; TASK NO. (443) 3103; WORK UNIT ACCESSION NO. H2

11. TITLE (Include Security Classification): Education and Training: 2010 and Beyond

12. PERSONAL AUTHOR(S): Marshall J. Farr (Allen Corporation) and Ray S. Perez (ARI)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Report	FROM 9/85 TO 12/86	1989, May	405

16. SUPPLEMENTARY NOTATION: Ray S. Perez, contracting officer's representative

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Biotechnology, Neuropsychology, Neuroscience, Education, Training, Army, Cognitive Psychology, 2010 A.D., Symposium

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This research note seeks to forecast scientific and technological advances in neuropsychology, neuroscience, biotechnology, cognitive psychology, and sociotechnology that may affect the way the Army educates and trains its personnel in the year 2010 and beyond. Eight papers were written by civilian scientists to identify potential breakthroughs. The papers were reviewed by a panel of civilian and military specialists to further focus on training and organizational implications. A two-day symposium was held whereby the authors presented their papers. Three separate workshops also were held at the symposium to address training and organizational issues derived from three possible future scenarios: predominant use of combat robotics, human soldier enhanced by automation, and soldier with enhanced human capabilities. Although a number of these issues were raised during the two day symposium, three major recommendations were made:
(1) to adequately address the training and organizational challenges that new breakthroughs may bring, ARI needs a multi-disciplinary staff made up of neuroscientists, (OVER)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: Ray S. Perez	22b. TELEPHONE (Include Area Code): 202/274-8694; 22c. OFFICE SYMBOL: PERI-II

DD Form 1473, JUN 86 *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

ARI Research Note 89-21

19. Abstract (continued)

computer scientists, robotic specialists, and sociotechnologists in addition to its regular staff of behavioral and social scientists

(2) to train both the professional workforce and the soldiers who operate and maintain complex equipment, the use of intelligent tutoring systems warrents serious consideration, and

(3) to ensure an effective integration of work performed by humans, robots, and other intelligent systems, training research on appropriate function/task allocation is needed.

Accession For	
NTIS GRA&I	☑
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

FOREWARD

The Training Research Laboratory of the Army Research Institute for the Behavioral and Social Sciences (ARI) performs research and development in areas that can help the Army more effectively meet its training mandate: both now and in the future. New knowledge and emerging technology are undeniably exerting their influence in many facets of civilian and military worklife. Every indicator suggests that life on into the 21st century will be characterized as a period of rapid change. The changing requirements and possibilities that will face the Army of the future present a challenge for those policy-makers who must plan and provide guidance for training and research activities. It was the purpose of the present project to contact a number of prominent scientists and authors in selected disciplines to submit papers which forecast how potential scientific advances may influence future training requirements and provide guidance for training research.

The report should be of interest to those in the military and training development communities who seek a better understanding of the conditions under which their programs will function in the future.

EDUCATION AND TRAINING PRACTICES: 2010 AND BEYOND

EXECUTIVE SUMMARY

Requirement:

As an aid to the development of long range planning, the Training Research Laboratory commissioned a number of papers from civilian scientists for forecasting scientific and technological advances for the year 2010 and beyond.

Procedure:

Eight individuals were selected to write papers on potential advances in neuropsychology, neuroscience, bio-technology, cognitive psychology, and socio-technology that would likely influence the way the Army educates and trains its personnel in the year 2010 and beyond. The impact of future technology on Army organizational structure also was examined. The papers were reviewed by a panel of civilian and military specialists to further clarify the training and organizational implications. A two-day symposium was held and attended by the authors, military planners, and senior scientists from ARI. In addition to presentations by the authors, three separate workshops convened to address training and organizational issues derived from three possible future scenarios: predominant use of combat robotics, human soldier enhanced by automation, and soldier with enhanced human capabilities. Following the symposium, working papers were prepared for summarizing symposium findings and for making planning recommendations for training R&D for the next 25 years.

Findings:

Three major recommendations are made. First, ARI needs to adopt a more multi-disciplinary approach for addressing the training issues associated with future scientific and technological advances. Needed will be neuroscientists, computer scientists, robotic specialists, and socio-technologists in addition to the traditional academic disciplines from which ARI draws. Second, the use of intelligent tutoring systems (ITSs) hold promise for the widespread training demands that will exist in the year 2010 and beyond. ITSs can be used for both professional staff and for soldiers who must operate and maintain complex weapon systems. Third, training research will need to focus on problems of task/function allocation and interaction between humans and robots and other automated systems capable of functioning autonomously.

Utilization of Findings:

These findings should serve as an aid to those involved in long range planning for training research.

EDUCATION AND TRAINING PRACTICES: 2010 AND BEYOND

CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART I OVERVIEW OF SYMPOSIUM PROCEEDINGS

INTRODUCTION

The purpose of this paper is to synthesize the professional papers and briefings gathered for a symposium entitled "Education and Training Practices: 2010 and Beyond," and, based on this information, to try to provide, as specifically as possible, a picture of what the world, the United States, and the U.S. Army will probably look like in the year 2010. Predicting the future, especially 25 years ahead, in the face of factors such as exploding technologies, rapidly changing geopolitics, cultural and population trends, and medical prolongation of life, is considered by many to be little more than educated guesses based on straight-line extrapolations from an existing state of affairs and technology. The critics of the "futurologists" claim that there is no way to figure in breakthrough technologies, some not even yet conceived of, which have yet to emerge, much less infer their impact on the social, industrial, political, and economic fabric of our nation. However, R&D planning must be carried out as far in advance as possible, especially (as is the case with training) when hardware technology is so intimately related.

Long-Range Army Training R&D Plans for 2010

The Army Research Institute recently set out, in a systematic way, to capture what experts in the various scientific disciplines bearing on training think the 2010 period would be like. Papers were commissioned by the Allen Corporation of America from a number of prominent scientists and authors representing the disciplines of neuroscience, robotics, biotechnology, computer science, physiology of learning, economics, and instructional technology. Appendix A contains a list of the commissioned papers, and provides information about the authors and their affiliations. The purposes of these commissioned "thinkpieces" were several: (a) identify and assess the influences that future concepts in the fields represented might exert by 2010 on the nature and role of the family, the world of work, educational institutions, demographics, the home environment, and the military; (b) discuss the effect of these changes in our social, economic, and political systems on the role of the Army in general and the individual soldier in particular; and (c) discuss the direct impact of predicted technological advances on training requirements and training technology of the 2010 era.

These papers were then distributed to several reviewers, to be critiqued from the standpoint of how practical and politically and militarily realistic they were. Appendix B identifies the reviewers for each paper. The reviewers included individuals who were (a) either active duty or recently retired Army Officers; or (b) scientists who had had extensive dealings with the Army. Together with ARI personnel and Allen Corporation representatives, the reviewers met on 30 April 1985 in Alexandria. The purpose of this full-day workshop/meeting was to have those attendees who were very familiar with the real-world Army discuss the merit and relevance of the commissioned papers. For the most part, these Army "experts" were the same individuals who had earlier submitted written evaluations of the commissioned papers.

Government R&D Efforts Relating to the Future of Training Technology

Prior to the symposium, the Allen Corporation commissioned a survey (Halff, 1985) of Washington-area federal R&D agencies to uncover information on their R&D planning activities that might have implications for Army training over the next 25 years. Special attention was accorded to telecommunications and biotechnology, since it was thought that they seem to present special promise for influencing training practices and technology in the future. However, the survey did not neglect government-sponsored research in other areas if they seemed likely to impact on future training. The survey report is organized around scientific topics; these include biotechnology at the molecular level, the neural sciences, cognitive science, and electronic educational technologies. This last category includes telecommunications in training, as well as computer applications to training.

Biotechnology is organized and discussed under the following headings: Recombinant DNA; monoclonal antibodies; computational biotechnology (e.g., using biological systems for information-processing purposes); molecular electronics (focusing on the use of "biochips," which are biological products that might replace silicon chips for the functions of computation and data storage); neural prosthetics (implants in the body that would interface directly with neural tissue); molecular biology (how biological "computing" in nature might be simulated at the molecular level to produce new processing and storage media); and neuropharmacology (biotechnology is involved here because genetic engineering, for example, may be used to manufacture the chemicals of interest).

There is reason to expect that biotechnology will impact substantially on training by requiring special training in how to protect oneself from, and effectively operate in, an environment of biological dangers created through genetic engineering. The soldier of the future will probably have to learn the signs of Chemical Biological Warfare (CBW), learn to interpret intelligence information on the nature of these threats, learn how to use biological sensors, learn how to treat himself and others exposed to CBW agents, and learn how to maintain effective functioning while wearing special protective gear which is likely to reduce mobility, flexibility, and comfort.

The survey report considers ways in which biotechnology may very possibly help create improved training technology by (a) making possible new kinds of training delivery methods (through, for example, an implanted, biologically engineered neural structure which appropriately encodes the material to be learned); and/or (b) enhancing the trainability of students by, for example, the use of pharmacological substances to increase learning rate, memory storage capacity, reasoning ability, or attentional resources.

For the most part, although many branches of the government show a major interest in biotechnology, the survey revealed that interest in training applications or even in intermediate technologies such as computational biotechnology is minimal. On the other hand, the federal neural-sciences community, in its attempt to determine the concomitants of neural function, are studying issues and problems which are much closer to some training relevance. For one thing, some neural sciences are looking to both psychology and computer science for explanations as to how the neuron functions as a tiny information-processing unit. For another thing,

cognitive psychologists (e.g., McClelland and Rumerhart at University of California - San Diego (UCSD) are now exploring theories of human information processing based on parallel activation models. This work is particularly germane to computer science which views parallel processing of information as a way to increase substantially the limits on conventional serial devices and memory architectures.

Continued progress in the neural sciences is seen as having two major consequences for military training. A direct application would involve chemicals and nutritional regimes for enhancing a soldier's physical and cognitive capabilities. An indirect benefit would be the development of new computational models and methods (based upon simulating brain functioning) which have training applications. For example, parallel activation models are particularly appropriate for modeling perceptual and motor functions which rely on parallel information processing. Such types of models might be used in training, for example, to specify precisely the problem-recognition skills needed for threat identification, to compute attentional load at different points in the acquisition of piloting skills, or to determine fidelity standards for visual and auditory stimuli in simulators.

In the realm of cognitive science, two research thrusts which appear to have future training implications were explored by the survey. In the area of skilled performance, expertise is now generally regarded as possessing both the required declarative and procedural knowledge peculiar to the skill or knowledge domain. We cannot, therefore, expect training to increase general intelligence and thereby instill domain-specific expertise.

Cognitive science issues such as human knowledge representation, on-line modeling of the student, and natural language will need much more research attention to bring about practical implementation of Intelligent Computer - Assisted Instruction (ICAI). And ICAI will probably be relatively routinely used in the training of many complex tasks in 2010. The key factor in the selection of ICAI as the instructional approach will be the availability and cost of adequate software and courseware. (From a computer science point of view, the storage capacity and processing speed of the hardware should easily be able to handle the Data Processing (DP) needs of the ICAI system.)

In surveying electronic training technology, contacts were made with agencies which "consume," rather than develop, this technology on behalf of research in education and training. Among the important areas that show promise for the 2010 era, the following are the major examples of those which were explored: (a) New approaches to simulation, especially stressing conceptual fidelity as opposed to fully realistic fidelity. The Navy's STEAMER simulator, designed to teach the operation and maintenance of marine power plants, is an example of a recently developed conceptual simulator. (b) As mentioned above, the hardware side of the technology to support future ICAI should be readily available. Where it is not feasible or cost-effective to program an expert system to serve as the basis for a one-to-one intelligent automated tutor, remote access (through telecommunications) to a human expert, with a video link-up, will permit on-the-spot, instant consulting assistance. (c) Automated curriculum development and revision, incorporating AI techniques and devices. (d) Technology of the future can make instruction feasible in areas now relatively neglected because conventional training is not able to supply the resource demands. For

example, computer-based simulation and gaming facilities can substantially increase the density of realistic practice, with intelligent simulated opponents, available to officers in tactical training. The design of more complex "microworlds," i.e., computer programs that permit practice and exploration in highly abstracted and simplified models of real-world situation, will be enhanced.

Army 21

Even before the ARI effort to formulate a long-range training R&D program began, the Army, several years ago, began work on predicting a future warfighting concept, describing how to carry out critical battlefield tasks. This project, formerly called "AirLand Battle 2000," and now known as Army 21, provides guidance for future planning in the areas of doctrine, personnel requirements, organizational structure, materiel development, and training in the 2000-2025 time frame. It is important to sketch some of the assumptions and probable scenarios considered by Army 21 in order to ensure that it and the ARI long-range plan are seen as essentially compatible.

Developed primarily by TRADOC, Army 21 envisions a greatly expanded battle area. The frontline as we know it today will no longer exist; instead, the area of conflict will be three-dimensional, 300 or more kilometers beyond friendly supporting forces, with a 360-degree orientation, and vertically extending to the limit of air defense weapons. The ultimate goal, in one likely scenario, is to present the enemy with a succession of unexpected, hit-and-run attacks more rapidly than he can react to them, to confuse him, and to halt his momentum.

Army 21 sees combat operations of the future as being planned and coordinated by a headquarters element termed a "battle task force," consisting of 50 to 100 personnel. This small element will include enough personnel and automated signal equipment to control up to six organic regiments.

Overall theater-level control of operations is foreseen as being exerted through the "AirLand Force," a C2 headquarters organization that will replace those currently considered "corps and above." The "AirLand force support command" will be the primary logistic support organization in the AirLand force, and will contain a logistics management center and a movements control center. The former will provide centralized management of assets and, through automated reporting, maintain real-time visibility of supply, maintenance, personnel, and medical support assets. The maintenance units of the support command will contain robots. Beyond minor adjustments and component replacements, virtually all maintenance will be performed by these robots and support personnel.

Significant examples in which robotics are expected to have a major impact include (a) a role in ammunition supply and resupply, in the form of "mobile ammunition reconfiguration modules," which will replace the familiar ammunition supply point, and be virtually personnel-free, being operated almost entirely by robotic loaders; and (b) medical and personnel services, similar to those performed currently, but with the assistance of automated 'thinking' computers and robots. (Wiltshire, 1985)

SYMPOSIUM ON EDUCATION AND TRAINING PRACTICES: 2010 AND BEYOND

The final major step in gathering information was a two-day symposium/workshop, held 13-14 June 1985 in Leesburg, VA, entitled "Education and Training Practices: 2010 and Beyond." The meeting was coordinated by the Allen Corporation of America, under contract to the U.S. Office of Personnel Management (Workforce Effectiveness and Development, Office of Training and Development). Appendix C is the Directory of Participants; Appendix D is the Agenda. The symposium had the overall objective of trying to focus, integrate, supplement, and refine the predictions and recommendations that had been made by the authors of the commissioned papers and the reviewers of the papers.

In order to accomplish this, some of the authors of the original papers were asked to present oral briefings which would recast their original papers to (a) reflect the comments that had earlier been made by the appointed reviewers (these had been fed back to them previously); and (b) to follow the general format and coverage typified by a set of briefing charts on robotics by Dr. Robert Finkelstein. Dr. Finkelstein's well-thought-out briefing was thought to be a superior example of a disciplined and useful model for organizing the material for ARI 2010. The discipline that Dr. Finkelstein's viewgraphs embodied included explicit (a) definitions of key terms; (b) military needs; (c) examples of manned vs. robotic weapons; (d) military applications of robotic technology; (e) a timeline of possible robotic evolution of technological breakthroughs and supporting technologies; (f) first-order effects (e.g., replacement of humans in dangerous tasks), second-order effects (e.g., changes in tactics), and third-order effects (e.g., changes in doctrine and strategy); (g) research issues relating to robotics; and (h) key implementation issues.

Another major purpose of the Leesburg meeting was to bring together, in one forum, the authors of the commissioned papers; their reviewers; selected military officers involved in long-range military planning (including COL David L. Miller, Jr., Project Manager for Army 21 at HQ, TRADOC, Ft. Monroe, VA); selected ARI personnel; several instructional specialists and OPM and Allen Corporation personnel. Once convened together, the intention of the meeting was to assign these kinds of mixed-background people to Working Groups which would be asked to review particular scenarios and objectives along a future spectrum ranging from complete replacement of most soldiers by intelligent automata, to the soldier who is augmented, for example, with expanded cognition and consciousness by means of drugs, nutrition, hypnosis, and/or electrical/magnetic cerebral stimulation.

The instructions given out to all attendees for each Working Group were deliberately designed to depict "pure cases" of the three most probable scenarios of the future Army battlefield. The following paragraph was presented first, to all participants, no matter to which group they were assigned.

> Each work group will assume a particular profile for a potential future Army combat environment. These environments or scenarios differ by the type of technology and the degree of automation expected to serve or dominate military organizations in the year 2010 and beyond. While differences of opinion exist regarding the extent to which the Army in 25 years will be shaped by highly

intelligent weapons systems and support equipment, it is apparent that the armed services will be making major decisions about the role they want advances in science and technology to play in support of the Army mission. Based on a spectrum of possible future technologies, we have posited three scenarios and have assigned each to a separate work group.

Assignment to a Working Group took into account the expressed preferences of all attendees, but also reflected the needs for balance, as determined by agreement between ARI and Allen Corporation personnel. Following the initial paragraph shown above, each Working Group member received the printed set of scenario assumptions and derivative questions and issues individually designed for his Group. Tables 1-3 provide this information.

TABLE 1

Directions to Work Group One: Predominant Use of Combat Robotics

Work Group One will assume a future Army environment which makes maximum use of intelligent robots. In this scenario, robots will do what armored vehicles and infantry personnel do now as well as carry out new functions as prescribed by the advancing technology. For example, autonomous robotic vehicles could move into an environment contaminated by nuclear, biological, or chemical agents, collect samples, assess the damage, and transmit information as to when the area is fit for human occupation. The primary function here of the human will be to anticipate and build into the robot (which need not be anthropomorphic) enough intelligence and sensor/output capabilities to handle most battlefield conditions. Removed from the area of conflict, the human will monitor the situation with the aid of intelligent interfaces to assess which alternative forms of intervention are needed.

The above sketch is provided to serve as a stimulus for your own work group discussions. It is not meant to constrain or steer your own thinking regarding the Army environment of the future. Work Group One should address the following objectives, however. Additional issues may be covered to the extent they aid in treating the topic under discussion.

(1) Provide a brief description or profile of a future Army combat environment which involves an extensive use of robots.

(2) Identify the research programs and enabling technologies that must be pursued to bring about such a scenario. In short, what are the intermediate technologies? In what sequence should they be met?

(3) Construct a time line, with estimates of the dates and associated milestones for reaching scenario attainment and the corresponding enabling technologies.

(4) Indicate the likelihood that the enabling technologies will be in place when needed. What are the associated risks and obstacles? What are some alternative paths?

(5) Describe strategies that could be used for handling truly innovative and unanticipated breakthroughs. Despite the apparent contradiction, is there any way of forecasting innovation?

(6) Assuming successful forecasting of combat robotic technology, what are the impacts on future military education and training practices? Can you construct a time line of these impacts? What are the important training research issues we should be addressing along this time line?

TABLE 2

Directions to Work Group Two: Human Soldier Augmented by Automation

Work Group Two will assume that the human soldier works in a thoroughly articulated, synergistic partnership with intelligent computerized aids. These can be portable expert systems which the soldier can query at will, using a large, non-restricting subset of natural English to ask for data and to give commands. In this system, the computer-augmentation system will not be a true, able-to-function intelligently-by-itself robot (Work Group One is working on autonomous robotic operations); instead, the computer-augmentation system will be the soldier's artificial, sensor-enhanced, eyes and ears. It will be the data base the soldier needs for his or her military occupational specialty. For example, it could help the soldier navigate, allow for self-propulsion, and, in fact, it may even have a small weapons-system capability which could identify, track, and hit enemy targets. It is quite feasible that the computer-augmentation system may be a small, pocket-sized, intelligent device, used primarily for information retrieval. It could serve as a job aid/expert system for preventive maintenance purposes or troubleshooting faults; it could provide map coordinates for facilitating navigation; and it could embody all the frequently needed decision rules to help soldiers perform their jobs better in both combat and non-combat settings. In brief, the system would serve to externally augment the soldier's cognitive, sensory, and motor performance.

The above sketch is provided to serve as a stimulus for your own work group discussions. It is not meant to constrain or steer your own thinking regarding the Army environment of the future. Work Group Two should address the following objectives, however. Additional issues may be covered to the extent they aid in treating the topic under discussion.

(1) Provide a brief description or profile of the human soldier augmented by automation.

(2) Identify the research programs and enabling technologies that must be pursued to bring about such a scenario. In short, what are the intermediate technologies? In what sequence should they be met?

(3) Construct a time line, with estimates of the dates and associated milestones for reaching scenario attainment and the corresponding enabling technologies.

(4) Indicate the likelihood that the enabling technologies will be in place when needed. What are the associated risks and obstacles? What are some alternative paths?

(5) Describe strategies that could be used for handling truly innovative and unanticipated breakthroughs. Despite the apparent contradiction, is there any way of forecasting innovation?

(6) Assuming successful forecasting of the future human soldier augmented by automation, what are the impacts on future military education and training practices? Can you construct a time line of these impacts? What are the important training research issues we should be addressing along this time line?

TABLE 3

Directions for Work Group Three: Soldier with Enhanced Human Capabilities

Work Group Three will assume a future where the soldier relies predominantly on enhancing his or her own physical and intellectual prowess without the use of external computer-augmentation systems. By 2010, it may not be too difficult to consider intelligent computer augmentation systems which are small enough to surgically embed within the body. It may be conceivable, given advances in surgical techniques and molecular biology, that implanted devices could communicate directly to special-purpose areas of the cerebral cortex to enable the human host to instantly access information with the ease and speed of human thought.

The 2010 era may bring us pharmacological agents that can augment the intensity, duration, and effectiveness of human sensory, cognitive, and motor activity. Expected benefits might occur in the areas of knowledge acquisition, short and/or long term memory, problem-solving activity, skilled complex performance, attention focusing, and endurance. Other sources for enhancing human capabilities may include hypnotic or post-hypnotic suggestion, and the development of para-normal or extra-sensory skills. These latter skills may range from remote viewing of enemy installations, telekinetic manipulations, and disruption of electronic transmissions.

The above sketch is provided to serve as a stimulus for your own work group discussions. It is not meant to constrain or steer your own thinking regarding the Army environment of the future. Work Group Three should address the following objectives, however. Additional issues may be covered to the extent they aid in treating the topic under discussion.

(1) Provide a brief description or profile of the soldier of the future with enhanced human capabilities.

(2) Identify the research programs and enabling technologies that must be pursued to bring about such a scenario. In short, what are the intermediate technologies? In what sequence should they be met?

(3) Construct a time line, with estimates of the dates and associated milestones for reaching scenario attainment and the corresponding enabling technologies.

(4) Indicate the likelihood that the enabling technologies will be in place when needed. What are the associated risks and obstacles? What are some alternative paths?

(5) Describe strategies that could be used for handling truly innovative and unanticipated breakthroughs. Despite the apparent contradiction, is there any way of forecasting innovation?

(6) Assuming successful forecasting of the future soldier with enhanced human capabilities, what are the impacts on future military education and training practices? Can you construct a time line of these impacts? What are the important training research issues we should be addressing along this time line?

Each Working Group was given three hours in which to meet, address the six objectives stated in the guidance, and develop a structured presentation of its findings to be reported back, by oral presentation of the Chair, to the plenary session.

Working Group Reports

For the most part, the products of the Working Groups were disappointing. In retrospect, it is not very surprising: they faced an extremely formidable, if not impossible, challenge. In just a few hours, they were supposed to agree on how to structure a 25-year-distant future so as to reflect the extrapolation of current technology, as well as emerging and innovative technology perhaps not yet dreamed of.

Working Group 1: Only W.G. 1 (Combat Robotics) was essentially responsive to the demands made on them by the guidance, probably because Dr. Finkelstein, a member of the Group, had already thought through, in fair detail, the advances in, and implications of, robotic technology. W.G. 1 endorsed the view that (a) robots will eventually carry out those tasks currently performed by humans; and (b) on the future battlefield, humans will not be present but will monitor robots. The group further posited that robots could be effectively used in performance of lower intensity (e.g., guerrilla warfare, surveillance, 'dull') tasks. Implications of the robotic movement were noted: new skill categories; fewer personnel; different educational/aptitude requirements; and changes in the organizational structure of the forces. Psychological research should be multidisciplinary and directed to pattern recognition, perception, and design of expert systems.

Remotely-controlled sensors, vehicles, weapons systems, and anthropomorphic devices already exist in either research laboratories, NASA, or the military. There is a Remotely Piloted Vehicle (RPV) platoon in the USMC, controlling vehicles brought from Israel. Teleoperator systems will pose an attentional burden on the serviceman who may have to track and control multiple objects or vehicles. Special training may be needed for this time-sharing skill. (At present, there is still controversy in the psychological literature over whether there is a general time-sharing ability and, if there is, whether it is trainable.)

The Army 21 document includes a section on robotics, prepared by medical scientists, who view robots as performing medical evacuation, first aid, and initial diagnoses in the field. Finkelstein also noted that there exists an Army Robotics long-range (20 years) plan. It does not assume any scenarios since it is technologically focused.

Working Group 2: This group, which regarded the human soldier of 2010 as augmented, rather than supplemented by intelligent devices, recommended five areas for such augmentation: sensory enhancement, available information, decision aiding, mobility, and communication. The man-machine partnership, via an intelligent interface, should enhance mental and physical endurance; flexibility as an individual and group member; and technical competence in using a variety of equipment in diverse environments ranging from the jungle to the city. "Emerging technologies" which would affect the future of education and training concerns were identified as brain chemistry; cognitive processes such as perception and attention; and "man-machine empathy."

Working Group 3: As the scenario handout for this W.G. explained, this forecast future assumes that the soldier will not be relying primarily on external computerized aids or surrogates. Instead, the human will enhance his cognitive and physical performance in a variety of ways: (a) through tiny embedded intelligent microprocessors which link his nervous system directly to the power and memory of a supercomputer; (b) through drugs which could, for example, affect concentrations of, and specialized receptors for endorphins; and (c) through paranormal communications and intelligence gathering. These enhancing techniques could facilitate information processing, concentration, sustained performance, and stress/pain management. W.G. 3 suggested research on the processes/phenomena of learning and memory, attention, arousal, and analgesia which are, respectively, biologically based primarily in the cerebral cortex, reticular system, limbic system, and the spinal cord/cortex.

DISCUSSION AND CONCLUSIONS

Training requirements in 2010 are going to be primarily determined by what the combat and support role and duties of the soldier will be. And that role will, in turn, be a function of the mission and role of the Army as an integrated component of our military forces, and will undoubtedly be strongly influenced by the technological zeitgeist.

In a real sense, technology advances are probably more predictable than the individual and combined influences of what we will call, collectively, geopolitical forces political, industrial, demographic, cultural, social, and educational changes to come. And, of course, technology itself will both influence, and be influenced by, all of these complex, interactive geopolitical-type forces. Army 21 assumes that the effects of these forces are unpredictable, and therefore posits any one of four possible scenarios based upon the tenet that the balance of power in the 21st Century will be uncertain. The four possible conditions that might exist are: (a) the same as our present state; (b) a new great power emerging; (c) chaos (presumably in the sense that the balance of power is unstable); and (d) one great power in ascendance. Regardless of which of these four conditions prevails, the Army must be prepared to fight in any location and in chemical/nuclear/ biological/ electronic environments where no single weapon system will dominate.

Given the fact that our nation cannot reach numerical parity with nations like the USSR or China, we will find technology essential for providing us with the needed edge. And the dominant, perhaps the strongest, technological groundswell taking us into the 21st Century is that of computers and automation. The silicon chip and the integrated circuit have revolutionized information storage and processing. Continued advances are accelerating as our industries and federal government agencies such as DARPA concentrate vast resources on crash programs such as SDI, and on winning races with the French and Japanese for 5th-generation computers which emphasize artificial intelligence (AI) and robotics.

The technological barriers to faster computers with greater storage and processing power will be breached, most likely, by advances in parallel processing, in molecular electronics (e.g., the "biochips" that McAlear predicts will afford us 109 devices per chip as early as 1995), and in

system-architecture concepts which will allow us to build powerful natural language/highly intelligent automated systems and interfaces. McAlear confidently asserts that molecular electronics and photonics open up the potential for advanced systems which may provide the basis for 6th-generation devices, which may have capabilities decidedly above human intelligence with speeds in the subpicosecond and of densities of 1018 or more switching elements per device at disk scale integration or larger."

To illustrate just how sweeping and pervasive is the onrushing wave of computers-and-automation technology, out of the nine "technologies for the future" identified in Army 21 we find AI, robotics, and smart weapons/brilliant munitions listed. An obvious and logical capability for the military that is already emerging from the technology of computer science and AI in the laboratory, and of manipulators and robots in the workplace, will be the increasing use of intelligent systems to replace, supplement, or augment many human cognitive and physical functions. The fundamental question as to what the individual soldier will be doing in and for the Army of 2010 lies in predicting which human functions, under what conditions, and to what extent, will be supplemented or enhanced by intelligent expert systems that are worn, carried, or embedded. Relatively straightforward extrapolations of current technology make it highly likely that the hardware, software, and system architecture capability for "highly intelligent" automaton (ultraminiaturized or in the mobile, self-propelling, and self-controlling forms of robots) will be readily within our grasp. Whether we decide to put this technology to work for us in any desired mode for any given task or MOS will be a function of cost effectiveness, hazards or severe demands of the workplace and jobs, and availability of intellectual resources to create the requisite expert system and do the AI programming.

The Army 21 list of expected "force and support characteristics" reinforces the prediction of extensive automation of battlefield weaponry, support systems, and personnel. We find in this list: "less manpower reliant, extensive use of robots, capable of continuous operation, mobility/survivability built in, energy efficient, redundancy where appropriate, disciplined, austere, and centrally directed and decentrally executed." Needless to say, other significant advantages of intelligent computers or robots seem obvious: they do not become ill, go on strike, need food, drink, or sleep, get lost, depressed, shellshocked, fatigued, or homesick. Congress need not be so crucially concerned with constituents who do not want their children drafted, nor with the expenses of military salaries, pensions, GI bills, and VA hospitals.

Certainly high tech equipment, especially based on intelligent systems, will be costly; however, the shrinking prices and sizes of chips and other electronic componentry, and the shortage of skilled manpower will combine to make the use of intelligent automata and expert-system-based devices cost effective for a good number of special purposes. Admittedly, also, robots and expert job aids will need to be maintained; but here again, the move towards built-in and automatic test equipment, plus modular fabrication/replacement and automatic repair capability should make the automata easily able to compete successfully in the marketplace against the unaided human. An Army 21 briefing slide entitled "Soldier/Machine Interface" is particularly germane here. Its contents include:

- High technology equipment will demand better training
- Future soldier may be less mechanically inclined
- Modular maintenance and repair required
- Advanced technology must reduce required soldier skill levels

Role of Soldier in 2010

All in all, it is a very safe bet that the 2010 battlefield will contain a significant proportion of intelligent robotic "people" (general-purpose robots who, like people, will demonstrate general versatility and adaptability) and robotic special-purpose machines varying in the quality and quantity of their intelligence. It is unlikely, even by 2010, that this degree and kind of intelligence will come close to a reasonably bright human. But it is likely that cognitive scientists, AI specialists, psycholinguists, computer scientists, and mechanical engineers will have combined their talents well enough by 2010 to have produced special-purpose programs and robots which have a unique kind of narrow, domain-specific expertise.

What we are likely to see on the future "battlefield" is a combination of intelligent robots (Working Group 1 scenario) and the human soldier working with one or more intelligent computerized expert-system-based aids (as described in the scenario for Working Group 2). There is no reason at this point to posit an exclusive role for either scenario. They both serve complementary and supplementary purposes. And in the case of the augmented soldier, there will still be a vital, critical role to be played by the human supervisor or officer who has to (a) decide which mode of automation meets his tactical and strategic needs; (b) ensure that the proper programming gets carried out; and (c) monitors the performance, locally or remotely, of his automation-assisted or fully robotic soldiers.

Changing Tasks, Role, and Organization

Given the above types of future scenarios, it follows logically that the main functions of the human in supporting and fighting for the Army of 2010 will be cognitive. The most important of these include:

1. Imparting operational instructions to (programming) intelligent machines. (This may well be done automatically, with no writing of code required, so that the human programmer can issue his directives or instructions vocally, in almost completely unrestricted natural language.) This initial (operating system) programming task will be done by experts at the factory, but can then be supplemented, when desirable, in the field by appropriately trained human technicians.

2. Giving orders on line, vocally, through minimally-restricted natural speech, to the expert system he is synergistically in partnership with. This will involve, essentially, interacting almost continuously with an intelligent interface in the performance of front-line or rear-echelon duties.

3. The men in charge of a squad, or any larger size team or collective unit, may find that those he commands include both robots and augmented soldiers. And among his robots will be differently

configured shapes, designed for a variety of special purposes. The robot can be shaped like man (i.e., be an android), or can have modular, replaceable parts which afford it special adaptability, mobility and safety. For instance, it can work effectively with plug-in "feet," jointed like man's, but allowing easy interchange with modular appendages such as snowshoes, wheels, and treads. The end-effectors of the "arm" can be replaced with a hook, a drill bit, a hammer, or any kind of power tool.

4. To keep track of one's own forces, to monitor, oversee, make policy for, command, and control them, the officer of the future will need, basically, to possess problem-solving, planning and decision-making, and higher-level cognitive skills. He will have to maintain a span of oversight and control over a variety of resources (men, augmented men, and robots) differing in amounts and kinds of intelligence and skills).

Training Implications: Content

Training R&D is guided by training requirements, and is reflective of (and sometimes reactive to) the progress of advancing technology. There are two major aspects of the 2010 era which will impact on training needs, and consequently on training R&D and the training process per se. One of these is what we train for (e.g., the content of training, which derives from an analysis of the job duties the soldier's MOS calls for). As these job duties change in the coming years, as MOSs become obsolete or newly emerge, instructional content will change. With this sort of change may come different levels of required mastery because one's faithful computerized aid or companion will both unburden the soldier of routine, tedious, repetitive, brute-force job-duties, and substitute more cognitively complex tasks. The already controversial psychological issue of how much "theory" the soldier-technician needs to be taught will become even more important to resolve. On the other hand, depending on how far AI progresses by 2010, the soldier will be able to rely on his intelligent computerized aid for expert advice. He can query its expert-system data base, for example, for probability figures on what might be causing a particular equipment malfunction. The Working Group 2 scenario discussed earlier provides some more examples of how the human and his non-human intelligent consultant will interact.

In addition to the above four exemplar roles of the future soldier, one generic training need will emerge as overriding: Each soldier will have to be trained not only in the special kind of "computer literacy" needed to interact and communicate with intelligent automata and interfaces, but also in how to work together with robots who are fellow members of one's team. Team training approaches in this context may require new approaches to instruction and attitude formation/change, and certainly warrants R&D attention.

Training Implications: Instructional Approaches and Delivery

Along with changes in what the role of the future soldier will be, and consequently what skills and knowledge he should be taught, the 2010 period will present us with a high-tech arsenal of instructional-delivery systems. Some of the very same technological developments that will lead to intelligent

robots and aids will also allow us to make use of the same expert-system-based intelligence to flexibly manipulate and control the instructional context, the speed, rate, and sequence of information delivery and practice, and the pedagogical strategies as a function of student ability. fundamental to this intelligent computer-assisted instruction (ICAI) will be the capability of the computer program to form and continuously update its pedagogical model of the student. The model, created and refined on-line by the intelligent program, depends on the ability of the smart computer to learn about the student by inferring from his learning behavior. The model will track the trainee's progress; diagnose his important misconceptions or bugs to understanding; factor in knowledge about the student's entering state, ability level, cognitive style, and preferred media; and decide what needs to be taught next, whether remedial attention is required, and how instruction should be organized and delivered.

By 2010, we should know how the above ingredients of an ICAI system's model of the learner interact to produce optimal learning, understanding, and retention. However, we will need intensive basic and applied cognitive and instructional research, starting as soon as possible, to investigate these interactions. Although delivery systems should become faster and cheaper and easily programmable by a subject-matter expert, the educational and psychological research to take full advantage of the high-tech instructional delivery system still remains to be carried out.

Of course, one may choose to direct training R&D dollars towards improving the hardware and software components of the ICAI systems, (e.g., the video disk and the intelligent interface between student and computer tutor).

The 2010 era will also bring us improved techniques for increasing the fidelity of simulation at much lower cost. Along with this will come computer technology which will permit, in the way that the Navy's STEAMER does, low-cost, high-quality conceptual simulation designed to teach, for example, a true understanding of complex causation and interacting subsystems. We should, therefore, mount more research to determine what kinds and quality of understanding and "mental models" are best taught by this sort of conceptual simulation. We also need research to yield criteria we can employ to decide whether to select full-scale faithful simulation or lower-fidelity training designed to promote understanding.

Training Implications: Focus On The Individual

The scenario described earlier for Working Group 3 cited drugs, hypnosis, and paranormal enhancement, as well as the more science-fiction-like increase in human ability through implementation of a miniaturized intelligent computer, in direct organic communication with the thought and action centers of the brain. Conceivably, by 2010, we will have gained enough knowledge of neurophysiology, biochemistry, bioelectronics, and all the other subspecialties of biology whose specific roles are relevant to understanding and influencing our thoughts and/or behavior. Although the state of pharmacological agents at this time makes them seem the best bet for increasing intellectual prowess, learning rate, effective memory storage capacity, and attentional span, brand new relevant technologies may emerge in the use of non-invasive electronic stimulation of targeted areas of the Central Nervous System (CNS).

Research should therefore be directed more intensively at "decoding" the brain's continuously-broadcast electric transmissions. Research on the P300 wave shows that the brain's responses to certain stimuli can evoke cortical potentials which are indicative of stages of internal processing of information. Since the recent techniques for studying neural and metabolic activity (e.g., brain imaging by computerized tomography (CT), or by positron emission tomography (PET)) have emerged, we can now obtain images of ongoing metabolic activity in various regions of the brain. PET, for example, can measure glucose and oxygen consumption patterns, thereby directing subtle increases in glucose use during tasks such as listening or remembering. It is not too speculative to assume that more powerful and specific ways of assessing brain activity and correlating it to stages of learning or performance will emerge by 2010. We need research to pinpoint the neural substrate responsible for learning, for responding, for memory, and for problem solving. It is possible that in 2010 we will be able to produce "designer drugs that will specifically affect selected brain functions and make them more susceptible to learning and other complex cognitive activities.

Hypnotic influence over memory, perception, and behavior is with us now. It can exert powerful effects, especially on motivation to learn, on attentional capacity, and on access to memories. Certainly, used appropriately, hypnosis can, in the opinion of some experts, do wonders to create receptivity for learning and memory. Research on the uses of hypnosis, drugs, and drug-assisted hypnosis to facilitate learning is strongly recommended.

PART II RESEARCH PLANNING RECOMMENDATIONS FROM THE SYMPOSIUM

INTRODUCTION

The US Army is currently involved in developing and planning a war-fighting concept document, Army 21, that characterizes what type of battlefield strategies are to be anticipated by the year 2010 and beyond. The intention of this document is to provide Army planners with guidance with respect to such issues as doctrine, personnel requirements, organizational structure, material requirements, and training and education.

The Training Research Laboratory (TRL) of the Army Research Institute (ARI), in an attempt to formulate a long-range plan for training research, solicited a group of experts, both military and civilian, from the fields of biotechnology, computer science, psychology, economics, and sociology. These experts were charged with providing assistance in defining a set of possible alternative scenarios that could represent the range of ways the combat soldier could function on the Army 21 battlefields. A two-day workshop was conducted bringing together experts, military planners and strategists and ARI scientists, to discuss the implications for training and education of three discrete scenarios. These were generated for the purpose of stimulating discussion and focusing the workshop participants on emerging and future technology and science that is most likely to impact on the way the Army trains and educates. The scenarios are:

- the extensive use of robots to replace the human soldier;
- augmentation of the individual soldier's abilities with electronic and mechanical devices and robots;
- enhancement of the individual soldier's abilities with implanted biotechnical devices, by pharmacological agents (drugs) or by the development of latent talents not currently part of military training. These scenarios, as formulated, were conceptualized as non-exclusive alternatives. It may well be that aspects of each may be realized to some degree. Nevertheless, it was felt that they represent a range of alternatives for which Army training elements will have to prepare soldiers.

The task facing ARI is to develop a long-range plan to provide the scientific basis for exploiting the training implications of these forecasted developments.

Scope of Future Challenges

The scope of research necessary is indicated by the breadth and variety of technological advances in the future that will impact on soldier tasks, as well as the ways they will be trained to perform these tasks. The research will be diverse, depending on whether the soldier will be replaced on the battlefield by robots, augmented by external devices, or enhanced internally.

Although the individual soldier may be replaced at the point of combat by robots due to the lethality of the future battlefield, many of the functions of battle such as strategy and command decisions will still be performed by humans. Therefore, soldiers in the future will have to be selected and trained to work with robots. Thus the selection and

classification criteria currently used by the Army will by necessity have to be modified to include assessment of aptitudes and attitudes toward robots; and the functions that are to be performed by soldiers probably will include highly complex cognitive skills that cannot be performed by robots. In order for a robotics program to advance to the point of approximating human activities and thinking skills, explicit models of how the human brain functions are required.

The soldier may be augmented by Artificial Intelligence (AI) in the form of "expert systems" that aid in such tasks as diagnosing equipment malfunctions or interpreting enemy actions on the basis of knowledge of the enemy's doctrine and tactics. The use of these decision aids will reduce the soldiers' needs for the technical content of their tasks, since the AI aids will provide them with a structured knowledge base. It will, however, be necessary for soldiers to be trained to use these AI tools; and AI-enhanced training systems or "expert tutors" will be used to provide individualized instruction for each trainee. In order for these intelligent training systems to be effective, it will be necessary to have explicit models of learning and brain function which will require advances in cognitive psychology and related fields of neuroscience.

With augmentation of the individual soldier by technological "extensions" that are designed to provide sensory enhancement, aids for decision-making, or rapid access to information, it will be necessary to design these extensions to be compatible with the needs, skills, abilities, and goals of the users. The interfacing of these tools with the soldier will require knowledge of cognitive information processing, perception, management of attention, and brain anatomy and chemistry. Prior to augmenting the visual system, one must know not only the microstructure of the perceptual system but also how it functions.

The enhancement of individual soldiers' capabilities will be possible only with additional knowledge in fields of learning, memory, perception, consciousness, and arousal. The study of neurological and chemical correlates of learning performance would enable the isolation of chemical neural substrates responsible for mood shifts, for learning, for memory, for problem solving, and so on. Further study could also provide the basis for the development of "designer drugs" which enhance specific abilities and increase some capabilities of soldiers without detriment to other abilities.

While it is feasible and possible to describe and predict the general requirements for research to support improvement of training and knowledge of human thinking for programming robots and the augmentation or enhancement of the individual soldier, it is not entirely possible to describe a definitive research program which ARI might follow for the next twenty-five years. It is even more problematic given variant external environmental conditions and reactions to conditions involving shift in U.S. foreign policy, demographics, geopolitical realignments and alliances. Thus the resultant research plan must be flexible enough to accommodate inherent error that is part of any forecast of future events. In order to develop a research plan for the Institute, it was necessary to forecast the likely progress to be expected in the behavioral sciences, along with estimates of the emergence of supporting technology over the next 25 years.

In the remainder of this report we have attempted to delineate and recommend in a planning format, the specific research, development, testing, and evaluation (RDT&E) activities to be undertaken by the Army Research Institute to help meet the Army's training requirements in the year 2010 and beyond.

Underlying Rationale

The above discussion relates directly or indirectly to one or more of the three scenarios described earlier. To review briefly for the convenience of the reader, the first scenario refers to an Army characterized by robots replacing humans or major human functions. The second emphasizes soldiers whose cognitive and physical capabilities are augmented by intelligent computer-based aids. And the third scenario envisions soldiers who will enhance their own physical and/or intellectual prowess without the use of external computer augmentation systems.

Some observations about these scenarios warrant mention at this point because they support the case for interdisciplinary research and suggest a logical basis for defending a rigorous scientific research program focused on paranormal powers, including techniques to train them.

The first two scenarios have more in common with each other than either one has with the third. This should not be surprising because these first two share the need for instant, unambiguous, "friendly", intelligent communication between humans and machines--whether the machines are serving as replacements for soldiers or as intelligent aids to make the soldier's job easier, safer, less demanding, and more accurate.

The third scenario of "internal" enhancement, although it does not assume machine guidance, is by no means competitive with, or exclusive of, the others. It is merely case-selected because it bears some promise of depicting future reality. A key issue with respect to its implications for ARI's R&D mission in training is whether paranormal abilities can, in fact, be trained. The obvious fundamental question one must ask is whether training can serve only to increase some already-present paranormal capability but cannot create and build it up if it doesn't already exist to some degree.

Although the serious study of paranormal capabilities is anathema to most orthodox scientists, one can make a fairly logical case for its theoretical existence. There is no doubt that the human nervous system, especially the brain portion, is an electrochemical system which is continuously sending forth complex electrical signals. Let us assume that these signals are uniquely different for variant thoughts and behaviors and are reliably associated with them over time. It follows that if one can identify (directly or assisted by external aids) certain wave patterns consistently associated with specific mental processes, it becomes more credible to posit controlled thought transference. Furthermore, if one accepts the hypothesis than an individual can selectively amplify and broadcast certain brainwaves, then these waves can be used to (a) penetrate the consciousness of people receptive to, and able to decode, incoming electrical-patterning of signals; and/or (b) influence the state of matter with which they come into contact (e.g., produce telekinetic effects).

Even if one does not believe that some humans have paranormal powers, it does not require a suspension of skepticism to appreciate that radio waves, for example, can damage the human central nervous system (CNS). In the 31 July 1985 issue of the Washington Post, Jack Anderson and Dale Van Atta reported on secret investigations by scientists "on both sides of the Iron Curtain" as to whether the mind ". . . can be short-circuited or even destroyed by extremely low-frequency radio waves (ELF)." Anderson and Van Atta assert that American researchers may, within 15 years, "learn how to interfere with the electrical impulses of the human brain by means of long-distance transmission of electromagnetic radiation". It is conceivable that people can be trained to transmit these interfering brain signals or, conversely, may be trained to resist enemy probes of electrical energy. Regardless of which training goal one chooses, certain directions of research are strongly suggested:

(a) to identify and decode human brain emanations;
(b) to control switching them on and off at will, perhaps using the biofeedback paradigm; and
(c) to control the direction, magnitude, and range of these brainwave vectors.

One could plausibly support the argument that basic and applied research into this cortical-electrical potential domain properly belongs, at least in part, in a training R&D program. What is being considered here is a set of processes, mental or psychological, which conceivably could be amenable to training techniques for shaping its direction and growth. Furthermore, basic research into the nature and interpretation of CNS electrical and magnetic activity also will help to identify and isolate the various neuro-transmitters and other body substances that are responsible for the organism's non-random emanations.

From an understanding of the brain's broadcasting patterns, it may be just a relatively short leap to discovering the pharmacological agents and nutrients for assisting the individual in learning how to achieve and/or increase control of particular kinds of paranormal abilities.

Research into the pharmacology of the human nervous system should be pursued for the promise of positively influencing learning, memory, and other cognitive processes. Gazzaniga (see Appendix A) speaks of the promise of peptides and other crucial molecules active in cell functions, as well as targeting memory-enhancement agents at specific cell groups. He sees neurobiology as playing a strong role in "assisting educability" in the 2010 period. We suggest that ARI needs to position itself better for the future chemical enhancement of biological functions (especially cognitive functions involved in acquisition, understanding, longterm retention, and transfer of knowledge and skills).

Possibly of significant importance is the use of drugs and other external agents to improve reasoning and problem-solving ability. Increases in these abilities can increase both learning capacity and long-term durable retention by promoting meaningful learning and understanding. It is important to realize that rote-memory skills and knowing a lot of unintegrated pieces of information will probably become steadily less important in the future, as cheap and powerful storage devices will be

readily available to everyone--serving, in effect, as direct extensions to the database resident in one's head. What AI will likely not accomplish by 2010, and possibly never achieve at all, is really to approximate a human's problem-solving, inductive/deductive reasoning capabilities. Undoubtedly a computer-based expert system can make human thinking and reasoning tasks less effortful or burdensome by supplying requested data instantly, relieving the individual of the encumbrance of holding too many data items in memory. To the extent that this may "free-up" cognitive resources and enhance decision-making and problem-solving processes, we may achieve some order-of-magnitude increase in the quality of a higher-order cognition.

There are obvious areas of research outside the jurisdictional domain of ARI which are not, at this time, realistic candidates to sponsor nor to investigate with inhouse resources. ARI may well decide, however, to maintain a "technology watch" over these areas which should consist of careful monitoring of scientific progress by other governmental agencies, academia, and industry. In this way, the Institute would have a firm knowledge base to allow it to decide whether it should step in and begin to take a more active, direct role in what is deemed a promising research direction which has grown closer to ARI's requirements, interests, and/or capabilities.

MEETING INTERDISCIPLINARY NEEDS

A strong conviction that there will be an increasing need for interdisciplinary research was expressed by the working groups which considered the three candidate scenarios. This viewpoint has some direct implications for ARI's internal personnel-selection and staff-training policies. Currently it is dominated by various types of experimental psychologists with specialties in training, industrial/organizational psychology, social psychology, personnel psychology, and engineering psychology. Other specialties such as operations research, mathematics, statistics, economics and computer science are represented to a lesser extent. If ARI is to take on R&D to implement the recommendations which follow shortly, it will seriously have to consider hiring a fair number of people in other areas, e.g., in relevant subdisciplines of biology, microbiology, genetics, biochemistry and psychopharmacology; in computer science (especially AI), in simulation engineering, and in psycholinguistics.

However, since the explosion in high technology has made the graduate-level people in these disciplines more difficult to hire by creating a shortage in their numbers, the Institute should consider at least the following three approaches toward meeting expanded interdisciplinary needs:

1. "Growing its own" expertise by encouraging and financing the current staff to become more knowledgeable about related disciplines. This can be accomplished by offering inhouse seminars, workshops, and courses taught or led by experts; paying for outside courses in local universities; and even sponsoring for selected promising individuals a longterm, matriculant-status, graduate education at high-quality universities.

2. Accomplishing the needed interdisciplinary work by sponsoring a greater proportion of contract research over inhouse research. In this way limited professional resources can be maximized in the sense that one indivi-

dual could actively monitor a much larger number of work units than could be done by performing the research personally. If this increase-in-contracting-out policy were to be implemented, it would affect the kinds of people ARI hires. Job applicants would then have to be judged in part on their willingness to devote themselves to monitoring someone else's research as well as on their aptitude for, and experience with, managing the R&D programs.

3. Sponsoring graduate education at appropriate universities in the short-supply disciplines. This could involve, for example: (1) providing tuition assistance, books, and living expenses for a candidate's graduate education on the condition that the individual become an ARI or government employee for some quid pro quo period of time (such as the military services often require); and (2) awarding grants or contracts to universities for interdisciplinary research if they agree to set up such a degree program (for example, cognitive psychology and computer science) and have its specific students work on the funded research.

It is important for ARI to realize that the greater emphasis on interdisciplinary research will be reflected across its own major research laboratories--in Training, Manpower and Personnel, and Systems. The three pure-case scenarios discussed earlier certainly imply greater collaboration among the technical labs. For example, teams of soldiers mixed with robots would require the talents of social/organizational psychologists to study team cohesion and the acceptance of robots as colleagues by their human peers. Engineering psychologists will need to be concerned with the design of the interfaces which are essential to effective communication with, and control over, intelligent automata.

PROGRAM 6: RESEARCH, DEVELOPMENT, TEST AND EVALUATION

The goal of RDT&E is to yield improved operational capabilities. The progression represents a multi-stage information-generation-and-conversion process characterized by the integration and conversion of knowledge within stages and knowledge-flow coupling between stages. The R&D process has been characterized as a way of progressively reducing uncertainty by buying information. In the earliest stages of the cycle, uncertainty is typically quite high as to the probable results and their value. Decisions on what to do and what not to do are made on the basis of expected value: the predicted value of the payoff if successful, multiplied by the probability of success.

For planning, funding, and review purposes, the Defense Department's RDT&E Program (Program 6) is structured into six categories, usually referred to in discussion and informal documents by the numbers of the categories under the DoD Programming System, viz., 6.1, 6.2, 6.3, 6.4, 6.5 (and 6.7 for the Army). Most DoD personnel involved with R&D are familiar with what the 6.1 - 6.5 categories stand for. Figure 1 is included primarily as a memory jogger for the reader. The category shown as 6.6/6.7 is somewhat less familiar to most researchers. The Department of the Army uses the 6.7 designation; the Navy uses 6.6 to refer to approximately the same stage of fullscale engineering development of systems which have received approval for production (as opposed to 6.4 which has not received such approval). The 6.6/6.7 designations are for convenience, since they are not used, as are 6.1

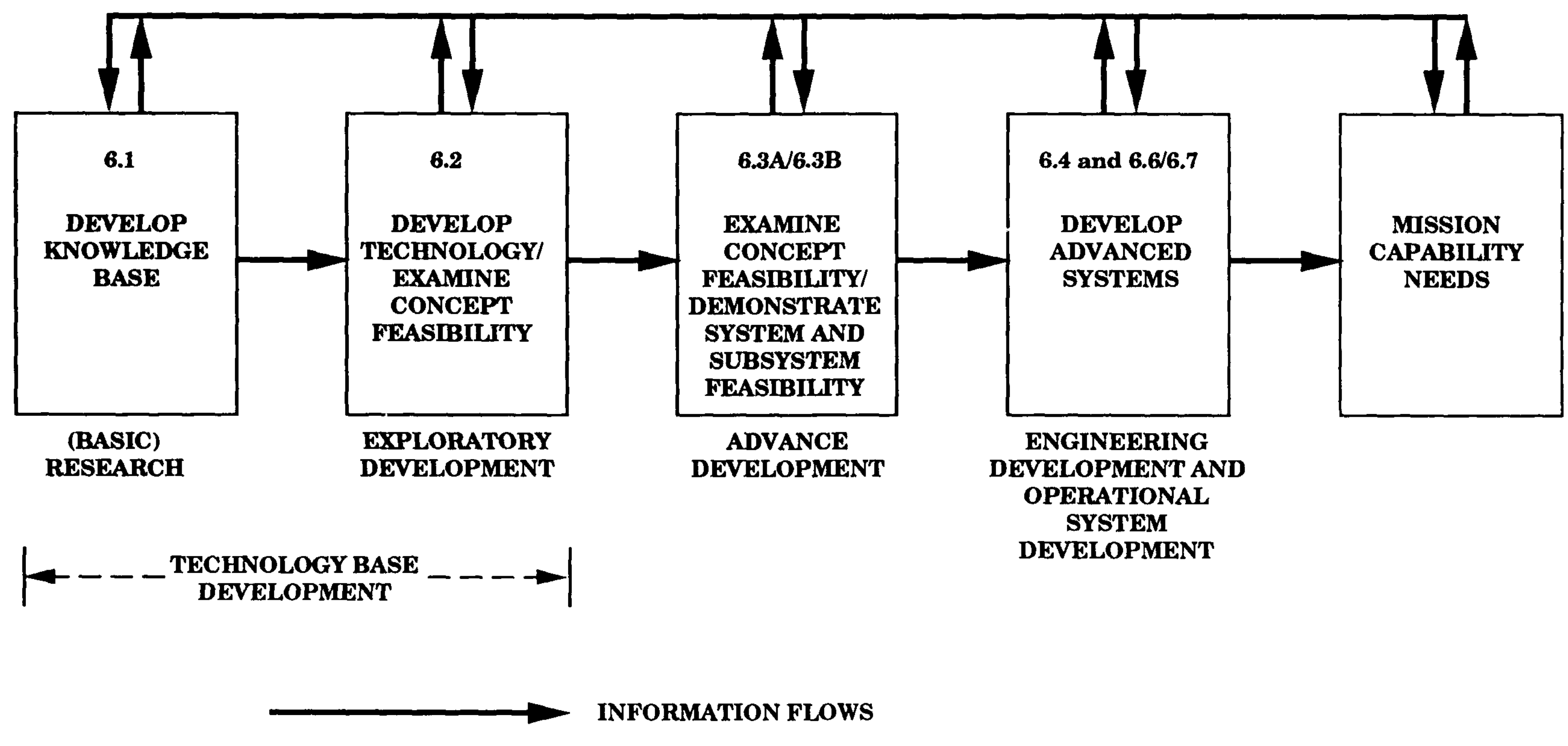


Figure 1
FUNCTIONAL VIEW OF THE DEFENSE RDT & E PROCESS

- 6.5, to generate program elements. Rather, programs listed under these convenience categories are included in other than RDT&E sections in the FYDP element structure.

The remainder of this report will employ the Program 6 (RDT&E) categories as conceptually useful stages to reflect the sequence of major steps needed to execute the recommended research programs. The reader must appreciate that:

(a) any more precise or narrow set of categories would be foolhardy to attempt for planning inventions, discoveries, and innovations over a 25-year span;

(b) most RDT&E planning is formulated for no more than a five-year look ahead;

(c) the RDT&E-cycle planning steps were created to meet the needs for hardware system procurements wherein components of a system could first be designed, tried out as a model, fabricated as a prototype, evaluated individually, and assembled into an integrated unit. Then this integrated system must be tried out, prototyped, and evaluated. (Obviously, a different model of a logical flow of R&D is necessary when information qua information is the target, or when courseware or instructional-strategy prescriptions are the desired products.); and

(d) for such a long-range planning horizon, each sequence will periodically--perhaps annually--have to be updated, refined and made more specific.

Each of the RDT&E columns in the following planning timetable charts should be allowed approximately five years to carry out. If we assume that the 6.1-phase will begin in the fiscal years 89/90 timeframe, then the 6.4/6.7-phase should be completed by about 2010. This timing will thus allow several years, following the RDT&E process, for formal classroom/operational environment evaluation of a target "product"--be it capabilities, techniques, systems, curricula, or software. One additional note about the "timetables" which follow: there obviously will be, in the actual execution of the research, overlapping stages. For example, a 6.2-phase may need to begin before the 6.1 leading up to it has been completed. Indeed, it is not unusual for 6.1 to continue for some years while work it has directly stimulated, or provided a base for, is undertaken at the 6.2 or even the 6.3 level.

In the planning charts which follow (Tables 4-9), the first column contains a brief statement of the program's objectives. In some cases, that column will also include a remark or two intended to provide clarification or elaboration.

TABLE 4

IMPROVED TUTORING AND ON-LINE DIAGNOSIS AND REMEDIATION BY ICAI

Objectives	6.1	6.2	6.3	6.4
Develop improved ICAI systems which are cost-effective, pedagogically effective, easily programmed, and maximally natural and "friendly."	Identify student characteristics and response patterns which program must continuously evaluate in order to form a model of the student and infer his misconceptions.	Develop demonstration ICAI programs for training of several MOS skills representative of major families of Army jobs.	Develop several different, complete mini-courses which employ ICAI as the dominant tutorial technique.	Perform cost-effectiveness evaluation of ICAI courses which teach complex skills and bodies of knowledge. Compare these ICAI courses for cost effectiveness with "dumb" CAI and platform instruction.
Central R&D issues include: A. Pedagogical: (1) On-line generation and revisions of model of the student. (2) Adaptive adjustment of instructional strategies. (3) Capability to infer student "bugs" from mixed-initiative dialog and generate appropriate remedial instruction. B. Computer Science and Psycholinguistics (1) Natural-language communication. (2) Speech recognition. (3)Computer architecture. (4) Expert system software. C. Ergonomics (1) Intelligent-inter-	Review literature to identify instructional strategies (e.g., Collins' Socratic dialog) most appropriate for ICAI. Demonstrate use of ICAI as part of an intelligent embedded training system. Basic research on knowledge-representation systems for optimal retrieval of information.	Collect data on student attitudes towards ICAI. Formulate criteria for analyzing which types of tasks and instructional needs are most pedagogically appropriate for, and amenable to, ICAI. Design and demonstrate "proof of concept" for a prototype, intelligent, <u>embedded</u> computer-based trainer. Develop expert system for the design and review of ICAI programs.	Evaluate (formative and summative) above courses with respect to meeting instructional objectives. Compare (experimentally) the pedagogical effectiveness of the ICAI courses with courses taught by traditional CAI and by conventional classroom instruction. Design and demonstrate "proof of concept" of a prototype expert system for ICAI by using it to generate several different ICAI programs automatically by interacting with appropriate subject-matter experts.	Develop a complete ICAI course which replaces one being taught by a non-CAI approach; test and evaluate it in actual training school. Conduct formal evaluation of expert system (for designing an ICAI program) in an actual Army training setting.

TABLE 5

ADVANCES IN SIMULATION CONCEPTS, TECHNIQUES, AND TECHNOLOGY

Objectives	6.1	6.2	6.3	6.4
Capitalize on new psychological approaches to, and technological advances for, improving training through simulation.	Basic research on: (a) New cognitive simulation philosophies and approaches (e.g., conceptual simulation for using mental models to teach understanding of complex-system theory and operation); (b) Incorporating AI into training-simulation systems to provide a unique, hands-on type of training capability; (c) Possible utilization of new technologies/techniques for more exact, realistic, and flexible simulation (e.g., holographic and computer-generated imagery, 3-D simulation); (d) Interactive tactical simulation in gaming formats, incorporating intelligent opponents, in individual and team-training contexts.	A. Design and fabricate functional prototype of an adaptive, computer-based <u>conceptual</u> simulator for one or more Army systems. B. Design a demonstration program incorporating AI into a typical Army system or sub-system simulator. C. Design and demonstrate prototype implementation of the most promising new and advanced simulator technologies referred to in prior (6.1) column under item (c). D. Design and demonstrate a prototype intelligent gaming-format simulator to provide training in team strategies for an integrated human-robot team.	A. Initial test and evaluation, in a laboratory setting, of a prototype of a computer-based, adaptive conceptual simulator. B. Demonstration of concept of AI capability incorporated into a training simulator. C. Experimental evaluation, in lab setting, of the prototype implementation of C., in prior 6.2 column, by incorporating these simulation technologies within appropriate training simulators. D. Experimental evaluation of the pedagogical and system effectiveness of the team-training simulator referred to in D. of the prior 6.2 column.	A. Operational T&E (evaluate both hardware and software effectiveness) of prototype of computer-based conceptual simulator. B. Operational T&E of a full-scale training simulator enhanced by AI capability. C. Operational evaluation of the full training systems which incorporate new simulation-technology implementation (see C. in 6.3 column).

TABLE 6

CONTROL OF ATTENTIONAL RESOURCES

Objectives	6.1	6.2	6.3	6.4
Explore approaches for improving quality and duration of attentional processes, such as time sharing, through training, inter alia, in component-task allocation, relaxation, meditation, yoga, and biofeedback.	Basic research directed at: (a) The determinants of attention, and the extent to which they are under voluntary control; (b) Natural time-sharing and division-of-attention tasks; (c) Mental-resource-allocation theories; (d) Relationship between brain-hemispheric specialization and cognitive-resource allocations; (e) Instructional strategies for reaching "automaticity" of performance; (f) Biochemical indicators of state of alertness.	Conduct experiments on humans to evaluate conflicting theories of mental-resource allocation, using military-type tasks as variables. Experimentally determine if attentional and time-sharing skills are trainable and, if so, to what degree. Explore feasibility of a device which can be worn easily in the field; monitors the user's cortical activity, and can detect and warn the wearer (and/or those around him) of an intolerable drop in his vigilance. Explore the feasibility of providing massive-practice training of individuals to achieve relatively rapid "automaticity" of performance for several suitable Army tasks.	Demonstrate and evaluate experimental programs, in lab setting, to train individuals in Army tasks which require time-sharing for successful execution. Design and demonstrate cortical-activity-monitoring device (see 6.2 column) for alerting wearer, team members, and system sensors of diminished attention and capability. Set up experimental training programs to demonstrate successful "automaticity" training of selected Army tasks.	Conduct and evaluate field tryout of alertness-monitoring device. Formally evaluate performance- and cost-effectiveness of "automaticity-training" programs for several important Army skills.

TABLE 7

NEUROPHYSIOLOGY AND BRAIN CHEMISTRY UNDERLYING LEARNING AND MEMORY

Objectives	6.1	6.2	6.3	6.4
Identify, understand, and predictably influence the neural-network substrate responsible for various cognitive processes implicated in learning and memory.	Basic research on correlations between brain activity [as measured, for example, by ongoing and evoked cortical potentials, computerized tomography (CT), and positron emission tomography (PET)] and independently measured cognitive processes (e.g., insight, understanding). Identify techniques for inducing brain states, by electrical or other stimulation, to make the individual more conducive to learning, understanding, and remembering. Basic research to identify and describe new crucial molecules (e.g., peptides) and neurotransmitters active in brain cell function.	Using infrahumans, experimentally create/induce cortical states (through chemical and non-invasive electrical/magnetic stimulation) which facilitate learning, understanding, and remembering. Identify the most promising experimental techniques as candidates for 6.3 follow-on.	Using humans and simple learning tasks, seek to experimentally verify (employing double-blind paradigm in laboratory) whether the candidate stimulation conditions demonstrated in prior (6.2) phase are successful.	Replicate step outlined in 6.3 (prior column,) but conduct experimental evaluations with soldiers in actual classroom or on-job settings, using complex material to be learned.

TABLE 8

TRAINING OF UNUSUAL ABILITIES

Objectives	6.1	6.2	6.3	6.4
Investigate training techniques to significantly enhance human abilities.	Investigate optimum conditions and paradigms for instrumental/operant conditioning and biofeedback-trained control of stress, pain, concentration, and relaxation. Identify cortical electrical patterns which are reliably associated with successful demonstrations of paranormal powers. Investigate possible relationships between an individuals attitudes, cognitive style, personality factors, and his ability to manifest paranormal behavior.	If a reliable association is found between cortical-wave activity and paranormal abilities, explore possible training techniques of feeding back brain-wave emanations produced by attempts to perform paranormal tasks in order to aid the individual to reproduce the specific brain states correlated with successful paranormal performance. Experimentally demonstrate that relaxation and stress reduction produced by biofeedback training can bring about improved learning and retention.	Conduct formal experiments, in laboratory settings, to prove concepts that: (a) individuals can be <u>reliably</u> trained to master biofeedback for facilitating learning and memory; and (b) Paranormal capabilities can be reliably trained via biofeedback techniques. Provide specification guidance to engineering design specialists and biotechnologists for the design and development of practical biofeedback systems to train functions that are important to learning receptivity and the control of paranormal skills. Develop preliminary tests for selecting individuals who possess paranormal potential.	Evaluate pedagogical effectiveness and cost-effectiveness of prototype biofeedback systems in formal training settings. Perform predictive validity study of selection test for identifying individuals with paranormal promise.

TABLE 9

BIOLOGICAL APPROACHES TO IMPROVING CAPABILITIES OF COMPUTERS

Objectives	6.1	6.2	6.3	6.4
Improving effective machine computation, speed, and retrieval operations by incorporating parallel processing, biochip circuitry, and other biological analogues.	Basic research into: (a) Animal and human mechanisms in parallel-processing systems; (b) The neural basis of memory storage and retrieval; (c) Circuits based on organic molecules ("bio-chips") which promise denser chip arrays and new kinds of information processing; and (d) Interactive activation models of human functions such as speech perception.	Explore conceptual feasibility and develop first-cut technology of computerized parallel-processing systems patterned after human interactive-activation models. Perform mathematical simulations of parallel-processing systems for data-base manipulation and retrieval. Develop a prototype model replacing silicon elements with either large organic molecules (i.e., digital biochips), or with analog biochip devices which would employ protein molecules (such as enzymes) as the computing elements. Demonstrate that major problems relating to material, fabrication, and performance have been solved.	Design and build alternative breadboard model(s) of computer systems based on parallel-processing architecture. Perform proof-of-concept feasibility studies. Identify components essential for a commercially viable biochip. Model them with CAD/CAM programs to analyze functional requirements and performance characteristics of different designs.	Build prototype models (using most promising system architectures for microprocessor "brain") of intelligent automata, ranging from hand-held-size expert system to full-scale robots. Evaluate engineering feasibility of producing a biochip-based computer. Evaluate the working biochip circuit in several alternative, special-function subsystems, embedded in more conventional computer circuitry, for such possible applications as robot vision and control.

REFERENCES

Halff, H. M. (1985) Government research and development efforts related to training technology. (Report 85-1). Arlington, VA: Halff Resources, Inc.

Wiltshire, J. R. (1985) Supporting the future force - Logistics in the 21st cent .ry. Army Logistics, March-April.

APPENDIX A

AUTHORS OF COMMISSIONED PAPERS

- DR. GEORGE MILLER - PRIMARY WORK ON COGNITION ANDLANGUAGE: CURRENT WORK ON THE EVOLUTION OF THE INTELLIGENCE TEST (COGNITIVE PSYCHOLOGY, PRINCETON UNIVERSITY)

- DR. MICHAEL S. GAZZANIGA - PRIMARY WORK ON ARCHITECTURE OF BRAIN, HEMISPHERIC PROCESSES (NEUROPSYCHOLOGY, SUNY)

- DR. PAUL LEVISON - SPECIALIZES IN THE IMPACT OF MEDIA ON INDIVIDUALS AND SOCIETY (SOCIOLOGY, NEW SCHOOL FOR SOCIAL RESEARCH)

- MS. MARILYN FERGUSON - NOTED SYNTHESIZER OF NEUROSCIENCE, EDITOR OF BRAIN MIND BULLETIN, AUTHOR OF "AOUARIAN CONSPIRACY" (SCIENCE JOURNALIST, SANTA MONICA, CA)

- DR. ROBERT JAHN - CONCERNED WITH THE POTENTIAL USE OF HUMAN CONSCIOUSNESS ON PHYSICAL WORK (PHYSICIST, PRINCETON UNIVERSITY)

- DR. LISA CARLSON - SPECIALIZING IN THE USE OF TELECOMMUNICATION IN SOCIETY (WORLD FUTURISTS SOCIETY, WASHINGTON, D.C.)

- DR. HAZEL HENDERSON - CONCERNED WITH THE IMPACT OF TECHNOLOGY ON FUTURE WORLD ECONOMICS (ECONOMICS, UNIVERSITY OF FLORIDA)

- DR. JAMES MC ALEAR - PRIMARY WORK ON THE DEVELOPMENT OF THE BIOCHIP (MICROBIOLOGY, GENTRONIX LAB, MD.)

APPENDIX B

LIST OF REVIEWERS

Reviewer	Author
Frank Burns Metasystems Design Group, Inc.	George Miller Robert Jahn
James McAlear Gentronix Laboratories, Inc.	Michael Gazzaniga Marilyn Ferguson
William Taylor Center for Strategic Studies Georgetown University	Paul Levinson Lisa Carlson
Amitai Etzioni Policy Forums, Inc.	George Miller Lisa Carlson
COL "Stretch" Dunn Professional Development of Officers Study Group U.S. Army	Paul Levinson
Elliott Jaques Consultant, Army Research Institute	Lisa Carlson

APPENDIX C
DIRECTORY OF SYMPOSIUM PARTICIPANTS

Dr. James Baker
Director of Automation
Allen Corporation of America
209 Madison Street
Alexandria, VA 22314
(703) 739-8002

Mr. Frank Burns
Metasystems Design Group Inc.
1401 Wilson Blvd.
Suite 601
Arlington, VA 22209
(703) 247-8301

COL L. Neale Cosby, Commander
U.S. Army Research Institute
PERI-ZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-8772

Ms. Brenda J. Dunne
Laboratory Manager
Princeton Engineering Anomalies
Research
C230, Engineering Quadrangle
Princeton University
Princeton, New Jersey 08544
(609) 452-5950

Dr. Marshall Farr
Consultant, Cognitive &
Instructional Sciences
2520 North Vernon Street
Arlington, VA 22207
(703) 524-8888

Dr. Robert Finkelstein
Consultant, Robotics
1001 Crestleigh Lane
Potomoc, MD 20854
(301) 762-8061

Dr. Jim Forbes
Research Psychologist
ARI Field Unit - Monterey
P.O. Box 5787
Presidio of Monterey, CA
93944-5011
(408) 242-8371

Dr. Michael S. Gazzaniga
Professor of Neuropsychology in
Neurology
Cornell University Medical
College
1300 York Avenue
New York, New York 10021
(212) 472-8296

Dr. D. Haggard, Chief
ARI Field Unit - Ft. Knox
Steele Hall
Ft. Knox, KY 40121-5620
(502) 624-3450

Dr. Henry Halff
Chief Scientist
Halff Resources, Inc.
4918 Thirty-Third Road, North
Arlington, VA 22207
(703) 237-0984

Ms. Pat Harris
Technical Editor
Allen Corporation of America
209 Madison St.
Alexandria, VA 22314
(703) 739-8076

Mr. Frank Hart
General Electric
Information Services Company
401 N. Washington Street
Rockville, MD 20850
Mail Drop 00B
(301) 340-4451

Ms. Hazel Henderson
Consultant, Economic Alternatives
P.O. Box 14977
Gainesville, FL 32604
(904) 373-2280

Dr. Kerm Henrikson
Principle Research Scientist
Allen Corporation of America
209 Madison Street
Alexandria, VA 22314
(703) 739-8069

Dr. J. Hiller, Chief
ARI Field Unit - Monterey
P.O. Box 5787
Presidio of Monterey, CA
93944-5011
(408) 242-8371

Dr. Robert Holz
U.S. Army Research Institute
PERI-SZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-9420

Dr. Robert G. Jahn, Dean
School of Engineering/
Applied Science
C230, Engineering Quadrangle
Princeton University
Princeton, New Jersey 08544
(609) 452-4550

Dr. Edgar Johnson
Technical Director
U.S. Army Research Institute
PERI-ZT
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-8636

Dr. Al Lining
U.S. Army Soldier Support Center
Attn: ATSG-DSS
Ft. Benjamin Harrison, IN
46216-5060
(317) 542-3884

Dr. Joseph P. Martino
Senior Research Scientist
University of Dayton Research
Institute
Dayton, OH 45469
(513) 229-3036

Dr. James McAlear, President
Gentronix Laboratories, Inc.
7503 Standish Place
Rockville, MD 20855
(301) 294-0400

LTC Mac McCaa
Long Range Planning Division
HDQ DA (DAMO-SSL)
RM 3B521, Pentagon
Washington, D.C. 20310
(703) 694-8241

COL David L. Miller, Jr.
Project Manager, Army 21
HQ TRADOC
Attn: ATDO-AP
Ft. Monroe, VA 23651
(804) 727-4159

Dr. George A. Miller
James A. McDonnell
Distinguished University
Professor of Psychology
Green Hall
Department of Psychology
Princeton University
Princeton, New Jersey 08544
(609) 452-5973

Ms. Grazia Narkus-Kramer
Project Manager
Training and Development
System Branch
Workforce Effectiveness and
Development
Office of Personnel Management
P.O. Box 7230
Washington, D.C. 20044
(202) 254-6940

Dr. Harry O'Neil, Director
Training Research Laboratory
U.S. Army Research Institute
PERI-IZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-8622

Dr. Clem Pangallo, Chief
Planning and Data Management
Branch
Policy and Systems Division
Office of Personnel Management
P.O. Box 7230
Washington, D.C. 20044
(202) 632-5650

Dr. Ray Perez
Training and Simulation Technical
Area
Training Research Laboratory
U.S. Army Research Instititute
PERI-II
5001 Eisenhower Avenue
Alexandria, VA 22314
(703) 274-8694

Mr. Billy Rutherford
Vice President, Eastern
Operations
Allen Corporation of America
209 Madison Street
Alexandria, VA 22314
(703) 548-4200

Mr. John Sands, Manager
Training and Development
Systems Branch
Workforce Effectiveness and
Development
Office of Personnel Management
P.O. Box 7230
Washington, D.C. 20044
(202) 632-6063

Dr. Robert Seidel, Chief
Training and Simulation Technical
Area
Training Research Laboratory
U.S. Army Research Institute
PERI-II
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-8838

Dr. Joyce Shields, Director
Manpower and Personnel
Research Laboratory
Army Research Institute
PERI-RZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-8844

Dr. S. Smith, Chief
ARI Field Unit - Ft. Benning
Attn: PERI-IJ
P.O. BOX 2086
FT. Benning, GA 31905-0686
(404) 545-1278

CAPT Jake W. Stewart, Jr.
Special Asst. to Under Secretary
of Defense
(Research & Engineering - *Long*
Range Planning)
Room 3E1034, *Pentagon*
Washington, D.C. 20301
(202) 695-0208

CAPT Donald Howard Zachert
HQS DA
Office of the Deputy Chief of
Staff for Personnel
Attn: DAPE-ZXP, Room 2D734
Pentagon, Washington, D.C.
20310-0300
(202) 695-7160

Ms. Connie Zweig
Executive Editor
Brain/Mind Bulletin
P.O. Box 42211
Los Angeles, CA 90042
(213) 223-2500
D 83707-0045
(208) 385-5242

APPENDIX D

Agenda

Symposium on Education and Training Practices: 2010 and Beyond

June 13 - 14, 1985
Xerox Corporation International Center
for Training and Management Development
Leesburg, Virginia

First Day

8:30- 9:00	Symposium Registration
9:00- 9:30	Opening Comments Jim Baker, Moderator, Allen Corporation John Sands, Office of Personnel Management Robert Seidel, U.S. Army Research Institute
9:30-10:00	COL David L. Miller, Jr.: Army 21
10:00-10:30	James H. McAlear: Molecular Electronics and Interaction with the Central Nervous System
10:30-10:45	Coffee Break
10:45-11:15	Michael S.Gazzaniga: The Possible Role of Neurobiology in Assisting Educability in the Year 2010
11:15-11:45	Robert Finkelstein: Combat Robotics of the Future
11:45-12:15	General Discussion
12:15- 1:30	Lunch
1:30- 2:00	George A. Miller: Some Psychological Perspectives on the Year 2010
2:00- 2:30	Robert G. Jahn and Brenda J. Dunne: Engineering Anomalies Research: Consciousness, Creativity, and the Horizons of High Technology
2:30- 3:00	Connie Zweig for Marilyn Ferguson: Training the Instrument: Back to the Real Basics in 2010
3:00- 3:15	Coffee Break
3:15- 3:45	Henry M. Halff: Government Research and Development Efforts Related to Training Technology
3:45- 4:15	Joseph P. Martino: Technological Forecasting with Confidence

Agenda (cont.)

4:15- 4:45	General Discussion - Explanation of Second Day Activities

Second Day

9:00- 9:15	Summary of First Day Session
9:15- 9:30	Marshall Farr: Introduction of Work Group Assignments
9:30-10:30	Break into WorkGroups: Work Group 1: Predominant Use of Combat Robotics Work Group 2: Human Soldier Augmented by Automation Work Group 3: Soldier with Enhanced Human Capabilities
10:30-10:45	Coffee Break
10:45-12:00	Continue Work Groups
12:00- 1:15	Lunch
1:15- 2:30	Complete Work Group Assignments
2:30- 3:30	Plenary Session: Reports from each Working Group (20 minutes per group)
3:30- 4:00	Discussion and Overview:
4:00- 4:30	Closing Statements

Evening Activities

Wednesday, 12 June	Hospitality Alcove in Cocktail Lounge 8:30 - 9:30 p.m.
Thursday, 13 June	Cocktail Hour 6:00 - 7:00 p.m. Dinner 7:00 - 8:00 p.m. Both in Central Dining Room

APPENDIX E

PROCEEDINGS OF THE
SYMPOSIUM ON EDUCATION AND TRAINING PRACTICES:
2010 AND BEYOND

TABLE OF CONTENTS

INTRODUCTION

The purpose of this introduction is to summarize the events and activities which led to a two day symposium entitled "Symposium on Education and Training Practices: 2010 and Beyond" held in Leesburg, Virginia on June 13th and 14th, 1985. The primary intent of the symposium was to examine areas of basic research likely to have potential for applying new findings and knowledge to Army education and training in the year 2010 and beyond. The focus of the symposium presentations was to examine new ideas and recent advances in selected areas of neuroscience; however, papers concerned with technological forecasting, engineering anomalies research, and combat robotics also were presented. With respect to the U.S. Army Research Institute (ARI) and the Training Research Laboratory (TRL) in particular, the ultimate goal was to identify promising areas of research with potential training impact and emerging technology which would serve as inputs for the development of a long range program of research.

Background

New knowledge and emerging technology are undeniably exerting their influence in many facets of civilian and military worklife. Virtually every indicator suggests that life on into the twenty-first century will be characterized as a period of rapid change. The changing requirements and possibilities that will face the U.S. workforce in the future present a challenge for those policy-makers who must plan and provide guidance for research and training activities.

A number of issues and questions have been raised by those who seek a better understanding of the conditions under which their programs will function in the future. What sort of skills and knowledge will be in greatest demand for our information-driven society in the years ahead? What impact will achievements in the emerging disciplines of neuroscience, biochemistry, physiology of learning, and cognitive science have on the way we educate and train in the year 2010? Will findings in these disciplines have anything to say about the "graying" of the workforce and the types of tasks most appropriate for an aging population? Will the mode of instructional delivery shift? With increases in electronic delivery of information, will instructors function more as managers of learning and less as deliverers of information? Will learning take place in more diverse settings? Will we have a better understanding of the individual differences that underlie the traditional lock-step learning process? What will the state-of-the-art likely be in 20 years in terms of genetic engineering, 5th, 6th, and 7th generation computing, home microelectronic systems, electronic publishing, instructional technology, and telecommunication? How can the Army, with its large civilian and military workforce, capitalize on these advances for potential resolution of future training needs?

It is realized, of course, that these are provocative issues and that no one individual will be able to respond to all of them. It was thus the purpose of the present project to contact a number of prominent research scientists and authors in selected disciplines to submit papers which forecast how potential scientific advances may influence future training requirements and provide focus for training research.

To identify emerging technology and scientific advances and to provide the desired input to a long range research plan for training, the overall effort was divided into four identifiable phases.

Phase 1 Initiate Call for Papers.

Immediately after the start-up meeting between ARI, OPM, and Allen Corporation, project staff started planning for the symposium. One of the first activities was to contact prominent scientists and authors to determine their willingness to submit papers and attend a two-day symposium. Prominent individuals in the following disciplines were contacted:

Neuroscience and Medicine
Molecular Electronics
Physiology of Learning
Cognitive Psychology
Physics
Computer Science
Technological Forecasting
Instructional Technology
Alternative Economics
Sociology
Science Fiction

Because of time contraints, individuals were first contacted by phone to determine their interest and were then sent a letter providing detailed information. Among those individuals with whom contact was made, a fair degree of interest in the basic concept of the symposium was expressed. A number of individuals declined as a result of conflicting schedules and other commitments and further contacts were made to insure an adequate representation of papers.

Eight authors originally prepared papers. These authors and the titles of their papers are as follow:

Dr. Lisa Carlson — Influence of New Models of Individuals, Work, and Organizations on Future Human Resource Technologies 1985-2010.
A sociologist's view of organizational structures and management strategies of the future.

Ms. Marilyn Ferguson — Training the Instrument: Back to the Real Basics in 2010.
Synthesis of leading-edge work in neuroscience and brain modeling.

Dr. Michael Gazzaniga — The Possible Role of Neurobiology in Assisting Educability in the Year 2010.
Molecular neurobiology approaches to understanding and enhancing memory processes.

Ms. Hazel Henderson	Impacts of Emerging Post Economic Paradigms in a Post Industrial World. Alternative models for assessing economic relationships.
Dr. Robert Jahn & Ms. Brenda Dunn	Engineering Anomalies Research: Consciousness, Creativity, and the Horizons of High Technology. Possible vulnerability of physical devices to influences of human consciousness.
Dr. Paul Levinson	Impact of Personal Information Technologies on American Education, Interpersonal Relationships, and Business, 1985-2010. Potential changes in institutions and relationships as personal computers continue to permeate American society.
Dr. George Miller	Some Psychological Perspectives on the Year 2010. Psychology of cognition and its application to psychometrics, communication, training, and computer technology.
Dr. James McAlear	Molecular Electronics and Interaction with the Central Nervous System. Advances in computer capability using molecular ("biochip") technology and the possible implications for human augmentation and robotics.

To this set of original papers, one other paper and three briefing papers were added to the symposium agenda. These included:

Dr. Henry Halff	Government Research and Development Efforts Related to Training Technology Survey of current federal R&D in the neural sciences, biotechnology, cognitive science, and electronic educational technologies.
COL David Miller	Army 21 The TRADOC and AMC concept for future warfighting; long-range planning guidance in doctrine, personnel, materiel, organizational structure, and training.
Dr. Robert Finkelstein	Combat Robotics of the Future Current developments in military and industrial robotics and their implication for the future battlefield.
Dr. Joseph Martino	Technological Forecasting with Confidence Techniques for predicting future technological innovations and implementation patterns.

After the symposium was completed, two additional papers were prepared by Dr. Marshall Farr in his role as project synthesizer. The purpose of the first paper was to integrate the events leading to the symposium and the proceedings of the meeting, and to succinctly summarize those areas of research and technology that were identified to have a likely impact on future training requirements. The second paper recommended specific research and development for future Army training. The titles of these papers are:

Forecasting Education and Training Practices of the 2010 Period.

Specific Research-Planning Recommendations for Training R&D by ARI for the 2010 Period.

Phase 2 Review Original Set of Eight Papers.

The submitted papers were first reviewed by a team of ARI and Allen Corporation research personnel. Areas of strengths and weaknesses were identified in the papers and authors were asked to add an addendum to their papers which addressed the deficiencies. The papers were then submitted to a second group of reviewers who also assessed the papers on their strengths and weaknesses. The second group of reviewers consisted of active or recently retired Army officers and scientists who had an extensive understanding of future military doctrine. Specifically, the reviewers were asked to assess whether the authors adequately described the emerging breakthroughs in their own areas of expertise such that a military planner or policy-maker could identify the implications on military training and organizational issues in the future.

Phase 3 Convene One-Day Review Conference.

A one-day review conference was held on 30 April 1985 with most of the paper reviewers and ARI and Allen Corporation personnel in attendance. Four major objectives were established for the conference: 1) to provide an opportunity for the paper reviewers to discuss their reviews, 2) identify the emerging knowledge areas that hold the most promise, 3) indicate how these areas are tied to future military training and doctrine, and 4) identify research issues and questions worthy of further investigation. Audio tapes recorded the presentations and ensuing discussion which in turn led to production of a hard copy transcript of the proceedings. The one-day conference helped to identify content areas in need of further coverage and also helped in shaping the planning for the two-day symposium scheduled for 13-14 June 1984.

Phase 4 Planning and Conducting the Symposium.

To insure the success of the symposium, a considerable degree of planning and coordination occurred among ARI, OPM, Allen Corporation and the contributing scientists. The objectives of the two-day symposium were: 1) to identify the important scientific advances and issues, 2) to assess the impact

and importance of these advances on military training in the year 2010 and beyond, 3) to forecast probable supporting technologies that will impact on how the U.S. Army trains its soldiers in the year 2010 and beyond, and 4) to identify and discuss the important future military education and training research issues. Those symposium contributors who had previously written papers were asked to prepare a 30 minute briefing including viewgraphs which summarized the highlights of their papers. In their first-day presentations, contributors were requested to follow a format which included explicit definitions of key terms, target populations, applications and examples of the emerging knowledge or technology, an evolutionary time-line of the emerging knowledge and resultant technologies, first-, second-, and third-order effects, research issues, and key implementation issues. They were also asked that their presentations reflect the salient characteristics of Army 21 doctrine which were provided in a handout.

The second day of the symposium brought together by means of work group assignments the various areas of academic and professional expertise among the invited participants. The basic idea was to assign the invited participants to three separate work groups. Each work group was given a potential future Army combat scenario which differed by the type of technology and the degree of automation expected to serve or dominate military organizations in the year 2010 and beyond. The first work group assumed a future Army environment which made maximum use of intelligent robots to replace what armored vehicles and infantry personnel do now as well as carry out new tasks as prescribed by the advancing technology. Instead of replacing the human soldier, the second work group assumed that the human soldier functioned in a thoroughly articulated, synergistic partership with intelligent computerized aids. The aids could function as a data base or portable expert system that the soldier could query at will to effortlessly carry out the tasks associated with his or her occupational speciality. Work Group three assumed a scenario where the soldier relies predominantly on enhancing his or her own physical and intellectual prowess through perhaps a combination of pharmacological agents, development of para-normal skills, and specialized training techniques.

Each work group received a sample scenario and a set of derivative questions to address. Each work group was given a three hour period to address the questions and report back to the plenary session with summary viewgraphs.

For an assessment of the successfulness of the symposium in meeting its objectives and for an analysis of the future training implications of the symposium's findings, the reader is referred to the papers by Dr. Farr submitted under separate cover. A copy of the verbatim transcripts of the symposium and viewgraphs from the major presentations and working group reports follow.

DIRECTORY OF PARTICIPANTS

Dr. James D. Baker
Director of Automation
Allen Corporation of America
401 Wythe Street
Alexandria, VA 22313
(703) 838 0045

COL I. Neale Cosby, Commander
U.S. Army Research Institute
PERI-ZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274 8772

Ms. Brenda J. Dunne, Lab Manager
Princeton Engineering Anomalies Research
C230, Engineering Quadrangle
Princeton University
Princeton, NJ 08544

Dr. Marshall Farr
Consultant, Cognitive & Instructional Sciencies
2520 North Vernon Street
Arlington, VA 22207
(703) 524-8888

Dr. Robert Finkelstein
Consultant, Robotics
10001 Crestleigh Lane
Potomoc, MD 20854
(301) 762 8061

Dr. Jim Fobes, Research Psychologist
ARI Field Unit - Monterey
P.O. Box 5787
Presidio of Monterey, CA 93944-5011
(408) 242-8371

Dr. Michael S. Gazzaniga
Professor of Neuropsychology in Neurology
Cornell University Medical College
1300 New York Avenue
New York, NY 10021
(212) 472-8296

Dr. Don Haggard, Chief
ARI Field Unit - Ft. Knox
Steel Hall
Ft. Knox, KY 40121 5620
(502) 624-3450

Dr. Henry Halff, Chief Scientist
Halff Resources, Inc.
4918 Thirty-Third Road
Arlington, VA 22207
(703) 237-0984

Ms. Pat Harris
Technical Editor
Allen Corporation of America
401 Wythe Street
Alexandria, VA 22313
(703) 548-4200

Mr. Frank Hart
G.E. Information Services Co.
401 N. Washington Street
Mail Drop 00B
Rockville, MD 20850
(301) 340-4551

Ms. Hazel Henderson
Consultant, Economic Alternatives
P.O. Box 14977
Gainesville, FL 32604

Dr. Kerm Henriksen
Principal Research Scientist
Allen Corporation of America
401 Wythe Street
Alexandria, VA 22313
(703) 838-0045

Dr. Robert Holtz
U.S. Army Research Institute
PERI-SZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-9420

Dr. Robert G. Jahn, Dean
School of Engineering/Applied Science
C230, Engineering Triangle
Princeton University
Princeton, NJ 08544
(609) 452-4550

Dr. Joseph P. Martino
Senior Research Scientist
University of Dayton Research Institute
Dayton, OH 45469
(513) 229-3036

Dr. James H. McAlear, President
Gentronix Laboratories, Inc.
7503 Standish Place
Rockville, MD 20855
(301) 294-0400

LTC Mac McCaa
Long Range Planning Division
HDA DA (DAMO-SSL)
RM 3B521, Pentagon
Washington, D.C. 20310
(703) 694-8241

COL David L. Miller, Jr.
Project Manager, Army 21
HQ TRADOC
Attn: ATDO-AP
Ft. Monroe, VA 23651
(804) 727-4159

Dr. George A. Miller
Professor of Psychology
Green Hall
Department of Psychology
Princeton University
Princeton, NJ 08544
(609) 452-5973

Ms. Grazia Narkus-Kramer, Project Manager
Training & Devel. Systems Branch
Workforce Effectiveness &
Development
Office of Personnel Management
P.O. Box 7230
Washington, D.C. 20044
(202) 254-6940

Dr. Harry O'Neil, Director
Training Research Laboratory
Army Research Institute PERI-IZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-8622

Dr. Judith Orasanu
Army Research Institute PERI-SZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-9420

Dr. Clem Pangallo, Chief
Planning & Data Management Branch
Policy & Systems Division
Office of Personnel Management
P.O. Box 7230
Washington, D.C. 20044
(202) 632-5650

Dr. Ray Perez
Training & Simulation Tech. Area
Training Research Laboratory
Army Research Institute PERI-II
5001 Eisenhower Avenue
Alexandria, VA 22333
(703) 274-8694

Mr. Billy E. Rutherford
V.P., Eastern Operations
Allen Corporation of America
401 Wythe Street
Alexandria, VA 22314
(703) 548-4200

Mr. John Sands, Manager
Training & Devel. Systems Branch
Workforce Effectiveness &
Development
Office of Personnel Management
P.O. Box 7230
Washington, D.C. 20044
(202) 632-6063

Dr. Robert J. Seidel, Chief
Training & Simulation Tech. Area
Training Research Laboratory
U.S. Army Research Institute
PERI-II
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Joyce Shields, Director
Manpower and Personnel Research
Laboratory
Army Research Institute PERI-RZA
5001 Eisenhower Avenue
Alexandria, VA 22333
(&03) 274-8844

Dr. Seward Smith, Chief
ARI Field Unit - Ft. Benning
Attn: PERI-IJ
P.O. Box 2086
Ft. Benning, GA 31905-0686
(404) 545-1278

CAPT Jake W. Stewart, Jr.
Special Asst. to Under
Secretary of Defense
Research & Engineering -
Long Range Planning
Room 3E1034, Pentagon
Washington, D.C. 20310
(202) 695-0208

CAPT Donald H. Zacherl
HDQ DA (DCSPER)
Room 2D734, Pentagon
Washington, D.C. 20310
(202) 695-7160

Ms. Connie Zweig
Brain/Mind Bulletin
P.O. Box 42211
Los Angeles, CA 90042
(213) 223-2500

Agenda

SYMPOSIUM ON EDUCATION AND TRAINING PRACTICES: 2010 AND BEYOND

June 13 - 14, 1985
Xerox Corporation International Center
for Training and Management Development
Leesburg, Virginia

First Day

8:30-9:00	Symposium Registration
9:00-9:30	Opening Comments Jim Baker, Moderator, Allen Corporation John Sands, Office of Personnel Management Robert Seidel, U.S. Army Research Institute
9:30-10:00	COL David L. Miller, Jr.: Army 21
10:00-10:30	James H. McAlear: Molecular Electronics and Interaction with the Central Nervous System
10:30-10:45	Coffee Break
10:45-11:15	Michael S. Gazzaniga: The Possible Role of Neurobiology in Assisting Educability in the Year 2010
11:15-11:45	Robert Finkelstein: Combat Robotics of the Future
11:45-12:15	General Discussion
12:15-1:30	Lunch
1:30-2:00	George A. Miller: Some Psychological Perspectives on the Year 2010
2:00-2:30	Robert G. Jahn and Brenda J. Dunne: Engineering Anomalies Research: Consciousness, Creativity, and the Horizons of High Technology
2:30-3:00	Connie Zweig for Marilyn Ferguson: Training the Instrument: Back to the Real Basics in 2010
3:00-3:15	Coffee Break
3:15-3:45	Henry M. Halff: Government Research and Development Efforts Related to Training Technology
3:45-4:15	Joseph P. Martino: Technological Forecasting with Confidence
4:15-4:45	General Discussion - Explanation of Second Day Activities

Agenda (cont.)

Second Day

9:00-9:15	Summary of First Day Session
9:15-9:30	Marshall Farr: Introduction of Work Group Assignments
9:30-10:30	Break into Work Groups: Work Group 1: Predominant Use of Combat Robotics Work Group 2: Human Soldier Augmented by Automation Work Group 3: Soldier with Enhanced Human Capabilities
10:30-10:45	Coffee Break
10:45-12:00	Continue Work Groups
12:00-1:15	Lunch
1:15-2:30	Complete Work Group Assignments
2:30-3:30	Plenary Session: Reports from each Working Group (20 minutes per group)
3:30-4:00	Discussion and Overview:
4:00-4:30	Closing Statements

Evening Activities

Wednesday, 12 June	Hospitality Alcove in Cocktail Lounge 8:30 - 9:30 p.m.
Thursday, 13 June	Cocktail Hour 6:00 - 7:00 p.m. Dinner 7:00 - 8:00 p.m. Both in Central Dining Room

THURSDAY, JUNE 13

Baker: I think we had better get started. My name is Jim Baker, and I have been asked to act as moderator for this meeting. As you know, the title of this meeting is the Symposium on Education and Training Practices: 2010 and Beyond. We are going to be listening to various experts tell us of developments in their fields that may impact on education and training in the year 2010, and thinking about what all that may mean to the Army as they contemplate the 21st Century, and the changes that will be occurring.

We are here under the auspices of the Office of Personnel Management and the U.S. Army Research Institute. We will start with a word from our sponsor, John Sands of OPM, the organization that manages this project with ARI by facilitating ARI access to contractor resources. John is the Manager, Training and Development Systems Branch, Workforce Effectiveness and Development.

Sands: Not recorded

Baker: Our technical sponsor is Dr. Robert Seidel who is Chief of Training and Simulation Technical Area in the ARI Training Research Laboratory. Bob lists his areas of research as computer-based and videodisc training, instructional systems research, technology transfer and program evaluation. He also notes under items of special interest that he has beach front condos to rent by the week or season.

Seidel: Not recorded

Baker: Many of us have heard of Army 21. Our next speaker, COL David Miller, is here to tell us all about it. He is the project manager for Army 21,

stationed at TRADOC headquarters. COL Miller lists his areas of research as leadership, organizational change, and English Literature. He is in the Field Artillery Branch of the Army.

Miller: I am pleased to be here, and the purpose of my briefing is to give you an overview of the Army 21 concept, TRADOC and AMC's view of the years 2000-2015.

The Army today is in a state of transition. New doctrine was introduced in 1982 with AirLand Battle. We have organizational changes to the light division and the new regimental system. New equipment such as the M1 tank, the Bradley fighting vehicle, the Blackhawk helicopter and the MLRS provide us with new challenges at every turn. Future technological advances will multiply these challenges.

Perhaps we should begin with a definition of terms. AirLand Battle is the Army's warfighting doctrine published in FM 100-5. Doctrine can also be how to fight and how to support. A concept is a general idea describing how to accomplish critical battlefield tasks. An umbrella concept is generic in nature and addresses operational and tactical levels of war. The present status of Army 21 is as an umbrella concept, not yet approved by CSA, that is not intended to replace AirLand Battle. It is a futures concept looking at the years 2000 to 2025. It will be worked through the concept based requirements system, CBRS.

CBRS, is shown on this slide as a circular format to emphasize that it is an open dynamic system. Feedback occurs all around the cycle, and it is structured so that we can integrate technological breakthroughs that occur as the cycle is in progress.

As you know, materiel development has had a technology focus, with R&D leading to equipment, followed by doctrine and organization. We are attempting to develop the concept first, and then develop organizations and training in accordance with the doctrine. This way, the concept would drive the system to produce equipment, doctrine, and organizations.

AirLand Battle is the Army's doctrine today. Army 21 will affect AirLand Battle in an evolutionary way over a period of perhaps decades. Doctrine is evolutionary. From the active defense of the mid-70's to Airland Battle of today, we have had changes in doctrine, and concepts that were developed but never became doctrine. AirLand Battle 2000, which also was published in 1982, caused some confusion because of the name; it was a concept, not doctrine. Focus 21 is intended to be the joint Army-Air Force approach to future warfare.

Army 21 is the TRADOC and AMC concept for future warfighting. It provides long range planning guidance for the period 2000-2025 in the areas of doctrine, personnel requirements, materiel development, organizational structure, and training. It follows the CBRS, is a dynamic concept, and will evolve into the Army of the future gradually over a period of perhaps decades.

The environment of the 21st Century will certainly be different from the present one. The balance of power will continue to be uncertain, and the only thing we can be sure of about the political and economic climate is that they will change. Energy and strategic materials will continue to be an issue, for fossil fuels are an expendable resource, and the U.S. continues its dependency on Africa for metals to build jet engines. The population profile will continue to change, with fewer eligible males in the population until 1990, and a slow increase thereafter into the first decades of the 21st Century. Our social climate will alter, with more issues arising, and less consensus on their solutions.

From the environment, our planners drew some implications for Army 21 which would be applicable regardless of future developments. The third item, "weapon parity dependent upon technology," is significant. Since a number of possible opponents outnumber us numerically, technology will have to supply us with an edge in weapons. To avoid decisive engagement, except at the time and place of our own choosing, will be essential, because of the critical nature of the first battles. Strategic mobility goes with our need to be able to fight anywhere.

Battlefield characteristics of the 21st Century are shown here. Depth may mean as much as 300 kilometers to the enemy's rear. Chemical, nuclear, and

electronic warfare must be considered in all our planning. The single greatest difficulty will be command and control. That has been the case in warfare since time immemorial, but it will be even more difficult in the 21st Century.

The essence of Army 21 is as follows: a style of waging war in which agility, deception, maneuver, and firepower are used to face the enemy with a succession of dangerous and unexpected situations more rapidly than he can react to them. Faced with an overwhelming numerical superiority, the outnumbered force has essentially two alternatives: die in pace, or maneuver to take advantage of economy of force. Four words capture the spirit of the operational concept of Army 21: 1) Scan - see the battlefield and detect the enemy forces; 2) Swarm - concentrate friendly combat power, not necessarily in physical configurations; 3) Strike - strike the enemy violently and swiftly; and 4) Scatter - rapidly disperse friendly units to avoid unwanted confrontation, and prepare to execute the process again.

The four tenets of the operational concept may look familiar since they evolved directly from our present doctrine, Airland Battle. I will describe them in detail in the following slides. It is particularly important to seize and retain the initiative. Independent action within the intent of the overall mission means taking advantage of tactical opportunities which may arise during the battle. Depth refers not only to time and space, but also to depth of resources. The battlefield will be enormously extended, perhaps to a depth of 300 kilometers. Logistics will be critical, as will the physical and mental readiness of the soldier.

Agility will be built into every system, organization, and procedure. It will be a mindset for commanders and staff officers. The application of the principles of maneuver and economy of force will be critical. Synchronization of all actions in time, space, and function will harmonize all actions with the commander's concept, and will give us a synergistic effect. The whole will be greater than the sum of the parts.

It is obvious that to achieve all the many capabilities mentioned before, Army 21 will be heavily dependent on technology. Artificial intelligence will be used to process the diverse intelligence inputs which will flood the command post. Robotics will help with physical tasks and will augment diminishing manpower. Brilliant munitions will follow smart weapons, with enhanced capabilities such as loitering over the battlefield and IFF capabilities.

These are the force characteristics we envision for Army 21 forces. They must be self-sufficient for three to five days, highly mobile, with greater firepower in smaller units. We must consider deployability in designing forces and equipment so that units will not exceed our capacity to get them to the fighting zone. Use of robotics will be extensive to accommodate less use of manpower. Vehicles will be able to cross moderate obstacles without waiting for engineer assistance. Redundancy will be a feature of all future equipment. Circuits will be trebled and quadrupled to avoid failure, and designs will permit "fail soft" modes where redundancy fails. A family of vehicles will provide a common chassis for cargo, combat, and artillery vehicles, reducing the volume and numbers of parts required for replacement.

This slide shows the levels of command envisioned for Army 21. The names are notional, generic terms intended to free our minds of preconceptions as to the capabilities of the traditional organizations. The Airland Force is a multiservice organization which will be permanently organized. There will be commander who has final authority, and we expect the organization to the tailored to the theater in which it is deployed. The Land Battle Force is the Army component of the Airland Force. It integrates, directs, and supports the land battle. The nearest equivalent in the present force is the corps, and we say that the Land Battle Force will have the operational and support capabilities of corps and some of the functions of the echelons above corps.

The Battle Task Force is the tactical control headquarters of the Army 21 force. It is a permanently organized command and control headquarters. This task force has the C2 capabilities of a present division headquarters, without the logistical tail. It will be small, perhaps only 100 personnel. The Close Combat Force is the basic combined arms fighting force of the Army 21

organization. The units conduct tactical operations to close with and destroy the enemy forces. It is composed of an optimal mix of organic combat, CS, and CSS units. It will be the size of a regiment with the firepower of a current division.

It has been said that in peacetime, we plan for how we will fight, but in wartime, commanders ask "where is my support?". Therefore Army 21 devotes an entire annex to logistics. Some of the support characteristics we envision are listed on this slide. Predictability refers to automated terminals to provide the commander with constant status of his logistical resources so that support can be provided when or before needed, rather than after something has run out. The support force structure envisioned for Army 21 has two parts. The Land Battle Support Force is organic to the Land Battle Force. It is responsible for logistics planning, management, and reconstitution of the Close Combat Forces. Particularly significant is the fact that this unit establishes the sustaining base for centralized management of logistics operations. The Close Combat Support Force is organic to the Close Combat Force. It performs supply, maintenance, transportation, personnel, and medical functions. The CCSF is equally as mobile and as well protected as the Close Combat Force.

We envision significant improvements in supply and services. Maintenance will be improved and simplified. Modular replacement parts, redundant systems and built-in test equipment, as well as an automated repair capability will reduce logistical manpower requirements. Transportation will also be improved markedly, with on-board navigation, NBC and ballistic protection, less terrain restrictive, improved aerial delivery system, and self-loading capability. A family of vehicles would provide multicapable vehicles with a minimum of parts required. Lightweight combat uniforms might include NBC protection, as well as environmental conditioning. Softlanding airdrop systems with a homing capability may become available.

The soldier/machine interface is a significant consideration of Army 21. We must consider the man first and then the machine afterward. High technology equipment will demand first class training, and we must be sure to put the burden on the equipment, rather than on the soldier. Stress will be a

very real factor to the commander in the future, since continuous operations will likely be the rule rather than the exception. The soldier of the 21st Century will not differ radically from our soldiers today. He or she will be a citizen soldier with the same beliefs in democracy, individual freedoms, and fair play found in our soldiers today. The soldier will be the product of an information based/high tech society where computer literacy is a reality. We also envision that women will make up a larger segment of the total Army.

In summary, then, Army is TRADOC and AMC's concept for warfighting in the 21st Century. It covers the full spectrum of conflict from low intensity to mix/high intensity. It is strongly dependent on technology, and complements the concepts based requirements system. The concept has been prepared for publication and dissemination is expected this summer.

The U.S. Army is indeed an Army in transition. The concepts based requirements system will be used to develop materiel in the future, with a four-year development cycle set as a target by Army Materiel Command. Airland Battle is our combat doctrine now, and Army 21 will be evaluated by rigorous analysis and wargaming.

Baker: If we are going to stick to our schedule, we will not have time for any questions at this time, but I'm sure there will be opportunity at the break for further discussion with COL Miller.

Our next speaker is Dr. James McAlear who is president of Gentronix Laboratories, Inc. Dr. McAlear lists his areas of research as biomolecular electronics and optrode prostheses.

McAlear: I appreciate being invited to speak to you today, and the one thing I hope to do is to challenge the basic assumptions about computer capacity. A few years ago at a NATO conference, it was anticipated that the silicon wall would not be very small -- lucky to get half micron, lucky to get much over 10 million devices per single chip. To base technology at 2010 on the idea that there are not going to be further major advances, I think is a gross error, a

grave error, a terrible mistake. This is not going to happen. It turns out that the numbers of effective devices per chip is going to increase, and continue to increase, perhaps at a greater rate than it has in the past. What we are talking about are potential errors in estimation of over a million times. This is very important because any consideration of robotics is going to depend entirely on what the robots are using for intelligence. I think that there is an absolute barrier in our thinking. We have come to the point where we will not accept the potential for robots - computers - that are smarter than we are. However, the hard data looks like the potential is there for devices that are not just smarter, but tremendously smarter than we are.

We have a very good idea of how many switches we have in our central nervous system. We know something about the algorithms that allow them to function, we know something about the speeds of the functional units, and certainly there are enormous differences between the hardware of life and the hardware of microelectronic devices. The fact is that we have a very, very slow computer, and the only reason it works is the tremendous amount of redundancy and content addressability that is built into it. The devices I am going to describe are not in the future; *they are here now.* In Japan alone, there are 1,000 scientists working in what is called molecular electronics. We know the companies involved and the level of effort. I would like to announce that for 1986 MITI has declared that they are going to have an initial budget of $36 million for research in this direction. That translates in terms of Japanese man years into over 500 people working in this area for that year. That does not include all the other companies that are getting into it. I have 25 Japanese coming to visit my laboratory on the 10th of July, and that is only the first wave. This is all since 1983 when we presented a talk at Maui at the combined IEEE Japanese Applied Physics Society. It was picked up by the press and now there are all kinds of articles about this sort of thing in the Japanese press and the Japanese economic journals. They have made a decision and are taking off, and we are probably at a lower level in terms of overall effort than they are. The point is that around 1990, there will be at least tens of thousands of people working in this field. I want to explain the reason why and what this has to do with the subject of this conference.

This is an article that came out in a German magazine after an interview with us that describes this development as a function of time. From the vacuum tube through the integrated circuit are described, then bioelectronics is shown as taking off around the year 2000. This is not accurate; it is going to take off about 10 years earlier. My reason for saying this is the numbers of people in the United States who have already gotten into this and the increase in interest in other parts of the government -- in the Air Force and the Navy and also at the Executive Branch. The Strategic Defense Initiative may push this development as well. What we are talking about in these kinds of devices is the successor to silicon technology.

We have just finished a nine-month study that is not published, a multi-client study, but I can leave you some information about the content that created a surprise in ourselves in that we discovered that there were far more people doing this sort of thing and they were far more advanced than we had imagined. We made an effort to organize this into a series of evolutionary stages. What we are talking about are 10^9 switches per chip by 1990 in conventional silicon technology. This is going to be difficult to do. I don't have time to go into the physical limitations in that technology but it is going to be very tough to meet those specs. As they succeed in developing 10^9 chips, by that time there will be many molecular film devices that will be equivalent to 10^{12}. Let me explain why.

Inorganic film equivalents exist. There was a review in Science last August that described some of these; they are multiple laser scan devices, thin films that function by means of a change that creates an excitonic reaction that changes the index refraction slightly and serves as an effective switch. These are addressable, and are relatively slow -- in the 30 nanosecond range. The advantage is that the multiple scanning gives them a tremendous amount of parallel processing, the whole surface is very active. The scanning laser beam is about a micron, so if you have a centimeter, you have about 10^8 addressable spots per centimeter. If you go to disc scale, as we are talking about with the thin film devices, then you can go up to 500 centimeters squared, which is about 5 times 10^{10}. In a thin film device, the switching speeds are not 30 nanoseconds but sub-picoseconds, in the order of a third of a picosecond, and that is the difference of over 30,000 times.

One of these thin film solid state devices could process about 1,000 real time TV signals in an A to D manner. Since the switching time is limiting, this may give you some of the enormous A to D switching capacity of these devices.

Where we come in is that so far, we are the only ones who have proposed any means of going into the third dimension on a disc-scale integration system - that is, a means of going from a thin film where you essentially get a zero or one equivalent for each addressable spot, to something that would be zero or n. N represents content addressability in this case, where at each point you immediately recover a body of information. Something like a computer bar code check out device, where you get a whole pattern. This is very much how the brain works -- parallel processing, content addressability.

Let me give you a model of a content addressable system. This was produced by Albert Lawrence at Hughes Aircraft. This is an infra-red signal, this comes from a Josephson Junction Oscillator, this goes into a 1-micron volume, this is a Josephson Junction Decapture over here. This is UV coming in this direction, this is an unspecified complex polymer, this is at crytogenic temperatures, liquid helium temperatures. What happens is that a UV input changes the affective infra-red spectrum, which passes through this 1-micron. This is a non-organized system, but this is not 0 and 1, but 0 and n. N can be very large. These kinds of models have been with us in our information network for a number of years, and the concepts are becoming much more mature. The possibilities of being able to go beyond thin film devices to complex, three-dimensional devices is real, and the rewards are absolutely enormous. We are talking about increases in affective capabilities which would take a 10^{12} elements per device and increase it up to 10^{18}. Another two quanta increase in potential computer power. Even dealing with 10^{9}, 10^{12} - let's not worry about 10^{15}. What we are talking about are devices that represent a larger jump from the present, from VLSI, than going from the single transistor to VLSI. The problem is how do we cope with that? What kind of robot is going to be controlled by something like that? It certainly is going to be smarter than myself or any of the other people I was drafted into the Army with. It's going to be smarter than any of the officers we had also. What do we do with it? I don't know; that's your problem. But what I am telling you is that the estimations about densities based on VLSI are

erroneous, and it is not going to happen that way. You had better go back to the drawing board and re-think this thing, because this is happening; it is real, and it is available to both sides. The Japanese are taking a lead in it so far, and the Japanese will sell it to the Russians. You had better believe they will.

Question (Zacherl): Speaking of your switching from 0/n divided by 0/1, does that have implications for analog devices, as opposed to classical digital devices?

McAlear: There are many, many different kinds of devices and different schemes for architecture that involve optical devices, and analog/digital -- certainly. There's just not enough time to go into it here.

Question (Zacherl): My second question is isn't this limited by the angstrom width of the laser?

McAlear: I'm glad you brought that up, because another wild card comes into this thing. We used to think that something like lambda being wave length over 2 would be about the limit, the defraction limit. It's not so. We are aware of the work being done at IBM Zurich on the optical stethoscope where they have used high index refraction wave guides coupled with small apertures and they are working with dimensions down to lambda over 100. It turns out that the Air Force Office of Strategic Research is funding a project at Cornell in the microfabrication center that uses the same principle. If you want to make a bigger exponent, and let's not talk about the addressability of a volume as being a micron or a square micron, let's talk about it being in the order of 100 angstroms, perhaps. This then increases the total addressable area by a factor of maybe another 10,000 times. We can try 10^{22}. How does that grab you?

Question (Finkelstein): While it may come to pass that the chip densities you are talking about actually happen and they probably will, it seems to me that this is just going to continue the current trend into the future, namely the software lagging more and more behind the hardware. To make a truly intelligent robot, intelligent in any kind of sense, even as smart as an ant,

requires not just a certain density, but also the correct architecture, which involves the software, the design of the hardware itself. What do you see, looking ahead, as far as the ability to provide some valuable software and architecture to accompany this hardware?

McAlear: I don't do that, but I have been talking to a lot of people who do, and they are very interested. They realize that when you get into this kind of hardware, then you have to re think the software altogether. What I am saying is that the process is going on. Robots are totally limited by the computer capability. I was quite impressed with how far they have gotten. I have been talking to people at the Odentics Corportation who make the ODEX. It seems to be the smartest one I've met so far. It has six legs and it walks and gets up and down out of pickups and lifts things. They are putting a laser scanning head on it, and this is going to allow it to approach the stairs and make all the decisions about the dimensions of the stairs before it gets there and it can go right on up. Now it has to stop, and is kind of slow, but this is LSI, not VLSI.

Question (Finkelstein): But if you take some simple organism like an insect, a bee, an ant. They have been around a long time, indicating they are successful at operating in their environments. If you had a machine that was as smart as one of these insects, you could probably accomplish quite a bit that was valuable, yet that level of accomplishment hasn't been achieved yet.

McAlear: Oh, I think so. Look at the Cray II; it has 250 pounds of microelectronics in it sitting in a cooler. It's LSI, not even VLSI.

Question (Finkelstein): What I am saying is that what could be looked upon as intelligent behavior of a machine at the level of an ant - where a machine could go off and go through a life cycle by itself, interacting with its environment, and so on. How many neurons does an ant brain have? You don't need very many. What I am saying is that the software to accomplish that hasn't even been done with the hardware that we have now.

McAlear: I think that most people would feel that it is not that difficult to build a VLSI ant, but we're not talking about VLSI. VLSI is stupid - 10^6.

The ULSI at 10^9, ultra large scale integration, which is ultra for solid state, but not for molecular electronics, that's a quantum. Let's go one, two, or three quanta beyond that, and you'll have a very smart ant. Very much smarter than my ant, and uncle, too.

Comment (Baker): One of the difficulties is that even if we don't have the breakthrough chip technology today, the fact is that we are on the verge of stepping into parallel processing. Parallel processing requires a whole different software architecture as well. The limitation may not be on the technology of the chip; the limitation very well may be first on the software to drive it, and secondly how to build the expert system to interact with that software. I think that's the point.

McAlear: All I'm saying is that our best guess is that the densities and speeds are going to continue on down for several decades. It is not going to stop in 1990. I have some things I could talk about with respect to optrodes and how these things might interact with neurons. It's a spin-off technology, but I don't really think it is that pertinent to what we are doing here. I made some copies of a paper I wrote; I'll leave those with you. The point I would like to get into just very quickly is to go through some of the technology that is now being looked at in terms of biotechnology.

This is a scheme for making multi-layered devices, used as the basis for our first smallest patent which involved protein-resist composites -- mixing proteins with a polymer resist in order to be able to apply technology from a field called ultracytochemistry to microelectronic devices. This has been carried out with the support of the National Science Foundation. We've demonstrated that we can deposit lines of silver in a lithographic pattern using electron beam lithography. This is a way of making a series of stacks of what amount to thin film transistors. This could be source-drain-gate; this could be gate-source-drain; whatever configuration desired. We look at these things as having application in multi-layer photon emitting arrays; displaced thin film arrays, and that sort of thing. Many of the kinds of materials that we can deposit including lead sulfide are materials of choice for photon emitting arrays, and the ultimates in lithography are not required for these kind of array technologies.

The kind of device which we think of as being pre Stage II that everybody is doing now, including groups at Johns Hopkins, GTE, Case Western, follow the interaction of laser light with a thin film. Here we have phthalocyanine interacting with laser light. The switching event that occurs in phthalocyanine is at a speed less than a picosecond, and the change is detected by a change in the Raman spectrum. The substrate here is an electrode; it may be a silver electrode. This is important because the Raman spectrum is enhanced by a phenomena called surface enhanced Raman spectroscopy. It increases the signal by six to seven orders of magnitude and that is quite important in this kind of device. The same kind of configuration can be switched using circuitive polarized yellow light. That has been demonstrated by Terrance Barrett who is now at NAVAIR. Together, these represent a means of writing and reading on a thin film system. Copper TCNQ, a molecule that acts similarly, is also being utilized at Johns Hopkins Applied Physics Laboratory. This can be switched and unswitched at room temperature.

Now I want to move quickly into the concept of these advanced three dimensional devices which we believe are going to be the next step beyond in 1990 through the year 2000. The achievement of this would represent extreme increases in density; this would give us another 10^6 increase in density of multiple laser scan devices. This relies on the capability of proteins to specifically associate with each other. This represents such a preparation; these are old electron micrographs, and show a unit antibody, for example. There are two parts of these, joined by FC's. If these are made appropriately, you can actually attach these in a ringlet. These are very discrete structures. This technology exists to enable the use of such molecules as tinkertoys, which have locks and keys, instead of holes and dowels. This is also represented by a US patent we obtained in 1978 that describes a resist, a layer of oriented protein on a substrate using electron beam lithography to cut open a window here, to use these oriented proteins and protein combinations as the beginning of a lithographic procedure - an analogy to a lithographic procedure in three dimensions. This somewhat reminds one of the change going from a single transistor to an integrated circuit. It is a fabrication technology, with a great deal of significance.

If I could have the first slide, this shows silver deposited by the technique I just described, a layer of polylycine was uncovered by lithography and a stain for basic protein is used to deposit silver. These are shown to be silver by their x ray fluorescence spectrum. We can make a micrograph which corresponds exactly to that configuration.

This slide is a little higher magnification, showing some of the details that indicates that these are in fact deposited by a precipitation reaction. We then carry on another procedure to enhance the amount of silver, and we can build these up as large as we want.

The next slide represents the meaning of life, if you will -- that's DNA, all done by computer modeling. This shows a tomato bushy stunt virus, and shows how protein self-assembled to form the structure of the head. This slide is part of the protein molecule which is important for molecular electronics. This is a porforin; porforins have the same structure and behave like phthalocyanines, but we can put porforins anywhere we want to in a three-dimensional array by protein self assembly. This shows a model for putting down an oriented monolayer and the building up a sequence of structures, A to B to C to D and so on, as is done by appropriate immuno and biochemical techniques. This is old technology; four billion years old. That's how we are all put together.

The next slide is a model that describes the kinds of tools that we have available for fabrication in three dimensions using molecular structures. One is an element of an oriented monolayer; this is a FAB antibody attached to it, this is a peptide interface. These are produced by computer modeling. There are now about two dozen computer modeling centers throughout the world; so far, about 300 protein molecules are known accurately in their three-dimensional structure down to the last atom. These are potential building blocks. In another five years, the number will certainly be well over 1,000.

This shows an antibody against an antibody. These can be used as tinkertoys, if you will. This shows a molecular array, without specifying the mechanism or the nature of that particular array that can be physically attached between two points. This shows that we can attach enzymes; that we

can use these enzymes to carry out reactions, depositing metals that can be used as conductors or used to deposit polymers which can be used as wave guides, stabilizing the structure at the same time.

This slide summarizes the tools that we have available. These can be used in many, many different combinations of three-dimensional arrays and structures, from sub micron on down to 10 nanometers.

This shows a potential array of these kinds of things where in one model a series of small conducting elements may serve as a super-lattice in a more or less conventional kind of microelectronic device.

I guess that's really what I want to leave you with. We have, as I indicated, just finished a multi-client study. I brought a copy along; I can't let you borrow it, but I can let anyone who wants to see it. To buy it costs $7,500; I'll accept checks. On the other hand, I think it might be appropriate if someone is seriously concerned about what I've said, to take a look at it. I hope that in throwing a stone amongst you, I might have hit somebody. I would like to offer it for you to look at in more detail; it is by far the most comprehensive source of information in this field today. Particularly for those of you who are concerned with the national defense, I'll say that I've left a copy with Admiral Poindexter in the White House and they are seriously concerned with this, as I did also with the Navy dealing with this subject and the Air Force. I'd like to give the Army equal time, if I could, and be happy to have you take a look at it as well. Thank you.

Baker: I'd like to mention something that came to mind when Dr. McAlear put up a slide that showed a patent request for some of the work that he is doing. Two weeks ago, I was out at an American Association for the Advancement of Science meeting in Los Angeles, and in a futurist session that I attended, a woman from the U.S. Patent Office gave a presentation that was a bit disturbing. She was doing an environmental scan of the patents applied for in high-tech breakthrough areas by country, as best they could project it and as best they could deal with the Patent Office's data bases. Unfortunately, the U.S. patent applications are on the decline and people like

the Japanese are on the ascent - startlingly so. It's compounded data because many of our multi national firms patent in other countries, but nonetheless, it says something about the need for more support of basic research to get the technology breakthroughs that we need today.

Getting back on target with the presentations, you will notice that our next speaker is Dr. Michael Gazzaniga. He's Professor of Neuropsychology in Neurology at Cornell University Medical College. His area is neurobiology of cognition, and memory and consciousness and problems of memory are areas of special interest and concern.

Gazzaniga: I don't know if you noticed last night, but at the welcoming booth there was a friendly sign by the Xerox company that said, "Xerox Future. Think About It; Don't Talk About It." All night, I kept having the feeling that I was talking about it, but not quite sure that I had really thought about it. With that caveat, I will offer this morning's remarks.

I think the question that the Army obviously would like a neurobiologist to address is whether there are imagined substances that are going to come out of neurobiologic research that could be used to enhance the capacity to learn and store information in a more efficient manner than presently is the case. In the paper that I prepared, since not only is the problem of memory new to me and therefore I was free to be generous, I outlined what was obligatory -- namely, to mention the wonderful molecular neurobiology approaches that have been initiated which will hold great discoveries about the actual molecular basis of mnemonic processes in the human. I'm not going to go over that, but am going to talk about the more conceptual problem of how to view memory and how other new medical technologies are teaching us about how complex the problem really is.

In an effort to be futuristic, I'm going to make a couple of strong claims. This is the best setting to make a strong claim - when you are really not accountable for it. What I come up with is this: a) There will be substances available within 25 years that will have profound effects on the capacity of the human to remember and, more accurately, to learn and acquire

information with greater efficiency. These will be coming out of the neurobiologic setting and available to society in general. b) Those substances will not be acting on the capacity of the brain to "store" information per se, but they are going to be acting on the attentional systems of the brain, the capacity of certain super-organizing systems to focus the individual on the task at hand. In making that claim, I am going to make the further claim that the wide individual variation seen in our capacity to remember and learn is not so much the differential capacity to actually store the information, but is in fact to focus on the issue at hand when studying the information. Having said that, and placing a major problem of "memory research" into the area of "attentional mechanisms," I will try to argue that there is a very tangible neurobiology that I think is on the horizon to address that issue.

To get where I want to go, I'll give you a slight history of the problem of memory as it has been conceptualized in neurobiology and cognitive science, and try to suggest how it has changed in recent years. I will then move on to the human neurobiology that studies patients with various kinds of memory disorders, and helps us gain clues about how complex this problem of memory is. The classic way of looking of memory, which is about two or three years old, came out of some beautiful studies within the framework of neurobiology of human neuropsychology and they were straightforward, as was the psychology supporting them. When we store new episodic information, there is a simple collection of the information in short-term memory. There is some kind of process that occurs that allows for the transfer of that information into long-term memory, and finally, into permanent storage within our heads. There was the claim that was widely reported of a patient with the hippocampus removed bilaterally who had severe problems in that capacity; information could not be consolidated and could only remain in short-term store, and that new memories were not possible. That sort of idea really seeped into neurobiology and cognitive science and has sat there, governing the field implicitly or explicitly for 20 years. That all started to change when other patients were studied and new tests were devised for this patient. It became clear that while this patient, probably uniquely in the history of neurologic literature, does have a very profound problem in learning new information, it turns out that he does learn new information under certain training

conditions, and that most amnestic patients in the neurologic field in fact learn, even though they do have this dramatic episodic forgetfulness of new information.

The work that sort of cracked this open was done in various labs. A particular study was done by a colleague, William Hearst at Princeton University, who made the point in studying a particular case with very severe amnesia, that the patient nonetheless could learn a very complex mathematical problem solving task over several testing trials. He said to the patient "2, 11, 19, __," and the patient was to figure out what should go in there. Over many, many testing sessions, the patient finally did acquire the strategy, and the strategy and learning capacity did stay with the patient. There wasn't a total blockade of information seeping into the nervous system after all. With that demonstration, in the last four or five years the field, I think, has begun to change its view, and has now decided that a more reasonable way to look at most amnesia is as follows: Patients who have memory disorders in fact have a profound recall problem when asked about information that has been newly presented to them. But if you use a variety of tests, cued recall tests, recognition tests, and other strategies, you find that the information is in fact in their brain. Somehow, it is in there, and the $64 question, of course, is why can't it be easily accessed and retrieved. What are the cognitive factors involved that are affected in these patients such that their recall is bad, but you can demonstrate that the brain is still recording the information. This is part of the story as to why I say that brain abnormality and difference in the capacity of us to remember in different ways is not so much in recording, but in all of the other systems that assist memory, and I want to describe a few of them to you.

It turns out that when we remember today or yesterday or anything, we remember it in a whole rich context of place, time, affective state, and all the rest of it. This issue had never been addressed in any serious way in the amnesia literature until William Hearst came along with some very interesting studies. He basically pointed out that one of the mechanisms that is down in a patient who is suffering from amnesia is that they no longer have the capacity to code information in time. They actually remember a series of events newly exposed to them, but they can't place them in their proper

relationship with respect to when they neard the information. Taking the simplest example, he gathered a group of New York hospital patients, patients who are very educated and very aware of the news and the world around them. He discovered that while they could report very well that a series of news events had actually occurred, what they were unbelievably impaired at was in telling you when they occurred in relationship to something else. For example, one of the tests when this work was done was "What happened first, the Sadat assassination or the attempt on Reagan?" At the time, that was an easy answer; if you can fish it out now, I'm impressed. But the result was that while they easily recognized that the events had occurred, the amnestics could not tell you the order in which those events had occurred, even though they had occurred the previous week. This test can be brought down to the laboratory situation where the critical issue is going to be tested within a one-hour span. Again, they demonstrated that while the information is in there in the so-called amnestic patient, the ability to have it tagged in a temporal context is defective. If you have a situation during a recall search where all events are equally probable in terms of a particular time, and are not nicely and orderly arranged, one can see how that can impair recall capacity. The cues that are there to be used in a recall situation are impoverished.

Another dimension of the amnestic patient, which speaks to these other systems that are involved in memory, is based on the clinical discovery that these patients are very flat in their affect after their particular cerebral lesion. You might have a lawyer who, prior to his neurologic insult, enjoyed cordon bleau, but is now quite happy to eat a Big Mac. While they used to like the opera, they are now quite happy to watch Mr. Rogers. They seem to have this flattening of affect. With that, one is not hard pressed to imagine that any new information coming in is not getting critical, salient cues assigned to it as to what might be more important than something else. To look at that idea, we actually tested empirically whether these patients could form preferences. There are ways of doing this in psychology, largely developed by a psychologist at Michigan named Bob Zion. What he discovered, among other things, is that the longer you look at something, the more you like it. This flies in the face of the current divorce rate, but that is what he found in the laboratory. The longer you look at something, the more you

like it, and you can do this in the laboratory where you show faces three, six, or 26 times, and with age/match controls, there is a nice relationship of preference being formed in an orderly way. Basically, in the amnestic's case, there was no ability to move his preferences around.

Another example that is more relevant to the issue of attention can be studied in another patient class -- the split brain patient. This is a demonstration to show you the importance of the attentional system in the processing of information and how subtly it can be manipulated in a way that, to the outside eye, you would not even notice. Yet, by its manipulation, you are changing the whole capacity of a brain system to store new information. How you do it in a split brain patient is very simple. These are patients who have had the big connection between their hemispheres cut for control of epilepsy. You can then train one side and test the other, or you can try to get simultaneous problems going in each half-brain. The simple test we used was to give word lists of one level of complexity to one half of the brain, and to the other half, we varied the complexity from easy to middle to hard. The question is by manipulating the lobes in this hemisphere, are you going to be affecting the capacity of the other hemisphere to store information in this word-list situation. We found, in fact, that you do affect the capacity of one half to remember the ten-word list as you manipulate the complexity of the list in the other brain. These are things that are very hard to measure other than behaviorally, and the way these things are explained is in terms of concept of attention, allocation of resources, and the fact that the brain has a set number of resources. If you call upon them, it has an influence on the capacity to sort information in another system.

These constructs, then, are really embarrassing and difficult for formal neurobiologists, because formal neurobiology has put all of its bets on the synapse -- that some type of synaptic change has to be responsible for mutability, for the system to store information. Studies are done ad nauseum to show how the synapse responds in orderly ways to particular kinds of physiologic stimulation, and that's all well and good. The problem is that neither neurobiology or anyone else has a concept that could conceivably explain how a synapse is ordering these other factors in memory research. These factors include spatial/temporal coding of new information, of the

salient features, emotional value of the new information, of how much attention is applied to the new information to see whether in fact it became encoded. Because of that, neurobiology has struggled deeply with this problem, and really hasn't gotten very far. I don't know what the ultimate answer to that is, except for the one I suggested in the paper - that there will be new models arising out of neurobiology as its knowledge of all the players in the brain game becomes better.

We can go beyond that, and look at human neurobiology and see if we can get the physiological support for the notion that there are these other mechanisms active in the memory process. What we did was to take the patients and have them studied metabolically through a relationship we established with the Positron Emission Tomography Laboratory at Washington University in St. Louis. What they discovered in the initial pass was interesting, but in some ways educated us in the limitations of data analysis of the PET scan. The PET scan, of course, is a way of measuring the metabolic or blood flow or blood volume capacity of the brain under resting and various kinds of specific stimulation conditions. When you do that and put the amnestics in the machine, you can get these coordinated studies of blood flow, metabolic rate, and blood volume, and these scans are then analyzed.

Prior to just a year ago, they were analyzed in a very crude way. You went into the problem with a theory, and let your theory guide what you looked for in a very data-rich situation, namely nine scans through the brain at different levels with differential information about flow, volume, and metabolism. You used very little of the data in the scan, but nonetheless, people obviously would have thought that the hippocampal or mesial temporal lobe of the brain would have some pathological characteristics, and these patients showed that. They showed that by a differential relationship, a breaking of a relationship between blood flow and cerebral metabolism; there was a de coupling. Metabolism dropped significantly in relationship to flow, where it remained coupled in other brain regions. This discovery was consistent with what was known about the importance of the hippocampus, and it was also interesting because the mesial temporal area of the brain houses coloneurgic systems which are known to be involved in various kinds of learning mechanisms. But that really wasn't enough, and it was sort of just

getting another measure of things that people already knew. It belied the power of the PET scanner.

We went back to the St. Louis people and asked them to get a statistician/ mathematician to look at all of the data on a PET scan. What one needed to do was to put up a theoretical grid on each scan, without a theory of what brain abnormality is actually occurring in this situation. They needed to find hidden variables that may be active in these pathological states. A man named Jim Molar, who has those skills, came to our lab, and this now has been carried out. We basically went through information given to us by Washington University and took a group of normals and a group of amnestics and took 41 measurements of brain areas in those patients. The question was could you find some co-varying region that differentially defines the normal from the abnormal patients with memory disorders. Using a combination of statistical methods including factor analysis and discriminate analysis, Molar has demonstrated very clearly the difference between these brains. The reason that this is very interesting to neurobiologists is that these patients, through CT scans, NMR scans, to neurologic exam, to biochemical analysis, under every classic measurement, are normal -- even though they very obviously are abnormal because of their behavior, and even though they very obviously have had some kind of schemic attack. The subtleties of the imaging techniques up to PET scanning, and the subtleties of analyzing the PET images, were not advanced enough to find these new brain areas that Molar unearthed with statistical methods.

What is interesting is that there are three main regions that co vary in the pathological state that explains the different space they live in with relationship to the normals, and these are brain areas that are very commonly thought to be involved in attentional disorders. These brain areas have a different pharmacology than the mesial temporal areas; they are more noraneurgic in their nature. This gives support to the notion, again, of how we think of memory. If you want to enhance memory, you should not be so concerned with the variation in actually being able to record information, but rather in the other systems that are very important in the management of new information such as attention.

I'll leave you with that notion. In studying memory in the future, what is really going to be important is to look at these other organizing systems such as attentional systems.

Question (Baker): Most of your data was derived from amnestics, and one of our concerns is the soldier, for example, who has to depend on memory processes in stressful situations. Can you get the same kind of dramatic effects from something like fatigue and stress in terms of biological and chemical impact?

Gazzaniga: Of course, the reason to use the pathologic case is just trying to figure out how the system works and get a model going, but I don't think there is any doubt that stress and fatigue deplete the resources of the system such that attention that should be applied in searching for information that they have or solving a problem are going to be severely taxed. Again, this is futuristic thinking, but whether or not there would be at that magic moment something that they would pop that would give their brain energy systems a surge up to their normal level of resources so that they could allocate them, I don't think that is Star Wars at all. I think that is very do-able, but how to do it is not known now, other than the obvious waker-uppers. The actual pharmaceuticals that would be used in that sort of situation are not clear to me at this point, even though there are these hints.

Comment (McAlear): I was very interested in the hippocampal information. A colleague, Professor Joe Moskal, has been making monoclonal antibodies against hippocampal surfaces and has succeeded in tracing histologically and also behaviorally. It looks as if he may have pinpointed substances that are able to modify behavior in test animals by using the hippocampal antibodies which must be involved as certain receptors. These are very likely the same kind of receptors that are associated with onocological associations. It gives a great deal of credence to the potential for modifying some behavior.

Gazzaniga: Yes. In my little paper, I pointed to the monoclonal antibody technology and showed how it's obviously going to be the case that more and more specific nerve circuitry is going to be identified that is involved.

Then what is going to happen is they are going to use monoclonals to tie onto particular pharmaceuticals or direct them to those circuits, and that kind of stuff. That's a lot of hand waving, now - there is a huge amount of work to carry that off, but that is how it is generally conceptualized in the field.

Question (Seidel): As a psychologist, one of the things that is fascinating to me is that it looks like the retrieval code is missing with some of these patients, and I was wondering if you had thought about the possibility of some kind of a prosthetic that might help the amnestics to reframe or provide those kinds of devices that he has lost?

Gazzaniga: That is a question that has immediate utility, because these are very smart people. They have IQ's of 140, but they just can't remember what happened at breakfast. They solve the problem naturalistically by copious notes which they constantly consult. But so far, there has been no pharmacologic intervention that has proved at all successful.

Back to that earlier question, there is work going on at Rockefeller by Bruce McKune that has shown that cortical steroid receptors in the brain are located in the hippocampus. One can easily imagine that under stress situations the whole hippocampal formation can be disrupted, and memory distorted. These are long jumps, now, but that is the context of a lot of people's thinking.

Baker: Our next topic has to do with robotics in the future. Presenting this to us will be Robert Finkelstein. Bob is a consultant on robotics, with combat robotics as his specialty. He comes with an interesting mix of background that includes operations research and cybernetic research. He is also president of the Capital Chapter of the Association for Unmanned Vehicles Research.

Finkelstein: This is a picture of the GI of the year 2025. Actually, this is to grab your attention, but it is not a cartoon; it is a real device that is being built by the Navy, and I'll go into this a little bit later. It is an interesting gadget.

First, the fundamentals of what a robot is. The word is a neologism, recent coinage in this century. Here is the background of it (slide 1). In that play, the robots rose up against the human masters and killed them all, which was maybe a portent of things to come. In fact, there have been a couple of human deaths due to robots, one in the U.S. and at least one in Japan. You can blame the humans for being careless; I don't think the robots were malicious. Then we have some definitions, things that I made up (slide 2). I would like to distinguish between them because sometimes they are used interchangeably. To me, any organism could be a cybernetic system because they are all goal directed. To me, that's the essence of it, although there are other characteristics. Therefore, some machines can be cybernetic systems. Artificially intelligent systems are those perceived to be intelligent, and that begs the question of "what is intelligence," which hasn't been answered anyway for human beings so why should it be answered for machines. It also implies that if you can have artificial intelligence, you can also have artificial stupidity. This means that the observer, the human being, looking on the behavior of a machine decides that it is behaving intelligently. To some people, a washing machine and a dryer might be behaving intelligently. They go through some kind of a cycle, and if you never saw one before, you would think it was incredible. This is an elusive characteristic of artificial intelligence that seems to be those techniques and processes that have been achieved and are no longer considered to be within the pervue of artificial intelligence; therefore, AI is anything that hasn't been accomplished yet.

Unmanned vehicles is the next category. This is my own avocation and I am active in an Association for Unmanned Vehicle Systems which historically has been focused on air vehicles because that is where the money was, DOD's money. It is now encompassing all kinds of vehicles in various other regimes - space, land, and sea, as well as air. Basically you are talking about vehicles that move translationally, as opposed to an industrial robot that is an arm that moves but the robot itself is fixed. These vehicles move about and behave as if a person were on board. That doesn't mean that it is autonomous necessarily; it could be what is called a remotely piloted vehicle or a teleoperated where a human being might be fully in the control loop somewhere at some remote location. Or it could mean that there is a computer

at another location, or that there is a computer and appropriate software on board the vehicle, in which case it is an autonomous vehicle which could also be behaving intelligently.

A robot can have a variety of definitions. The Japanese have an official definition that I am not entirely satisfied with, but it tends to encompass a number of things including what in the U.S. might be called automatons, and not really robots. Up to this point, robots have been fairly stupid things without sensors, blind, with very limited ability to interact with the environment, but the direction for true robotics is going to be what the science fiction writers have always envisioned, what Isaac Azimov has said all along -- where you have a machine that incorporates sensors analogous to the human senses, effectors analogous to hands, arms, feet, the ability to interact with the environment. That distinguishes a robot from a computer, and if you want to look at it from the other point of view, a computer can be looked upon as a quadraplegic robot. There could be a sensor on the computer, but it sits there; it does not interact physically with the environment. And, of course, a processor has to be a key thing. Just like the human brain distinguishes human beings from other organisms, the processor has got to distinguish the robot from other kinds of machines. The processor is not only the hardware, but it also has to be the software, as well.

Here are some quick pictures of some kinds of robots. These are just some typical views of what people think a robot is now -- a piece of machinery in a factory that works along a conveyor belt and handles things, pre-programmed but has no sensors. There are very few in operation that do. There are also some personal robots coming about, some of them quite sophisticated. This one has a mini-disc drive and several processors on board and various sensors. Despite this relative sophistication, none of them do anything useful unless you want to spent several thousand dollars for a vacuum cleaner or a smoke alarm that will wander around the house. Here's one the Japanese have that can play the piano so you don't have to bother taking lessons.

As far as the military is concerned, a manned system is heuristic in the sense that a human being works with rules of thumb, and doesn't follow stringent algorithmic processes like a clockwork automaton or computer

program. If you split the person and the weapon, the weapon is algorithmic. With a rifle, you go through a certain sequence and it releases a bullet out the end of it. Any weapon that people have been using up to now is a fixed sequence device. You combine it with the person and you have a heuristic system. The idea is to take the person away from the weapon in space and maybe also time, and have the weapon itself be heuristic - flexible, adaptive, able to deal with circumstances not foreseen by the designer.

There are general applications in the various regimes. In space, the planetary explorers that NASA has been launching are, of course, robots by most definitions. They are not extremely intelligent, but a robot doesn't have to either look like a human being or act like a human being. If we get a robot that behaves as intelligently as some of the lower organisms, even below mammals, you can get some very useful behavior out of a machine. That, in general, hasn't been done yet.

There are all kinds of military activities in the air regime or medium -- a lot of reconnaissance, surveillance work, remotely piloted vehicles. The Israelis have been very active in that, and that woke the Navy up during Lebanon and they realized that sending $20 or $30 million high performance air planes with people on them to do a mission that could be done by a couple of hundred thousand dollar little expendable vehicle was a total waste. Let the political embarrassments and tragedy when at least one airman was killed and another held hostage be avoided. Since that time, the Navy has been extremely active. The Army is developing a system, and so on. The reconnaissance/surveillance mission is a relatively easy mission to accomplish, either through a teleoperator controlled with a link from the ground, or semi-autonomous, or autonomous. Beyond that, the kamikaze mission has a very great potential for revolutionizing warfare, totally changing the nature of warfare. It answers some of the problems involved in designing the military for the next century. In the communications relay aspect, the air vehicles of a category called high altitude, long endurance where we could send up a vehicle for days, weeks, or months are what amounts to a low altitude satellite. You have a platform up at maybe 65,000 feet, and if they can loiter around the same area for weeks or months on end, you have a geosynchronous satellite. You can use them for communications relays,

reconnaissance and so on and this has some importance for strategic as well as tactical applications, and there is a lot of work in that area as well.

In the other two regimes, there is a lot of work, although not a lot of money yet, in underwater unmanned vehicles. They are working to build an unmanned submarine that can travel thousands of nautical miles and do some missions maybe in somebody's harbor and then come back, or maybe do some anti-submarine warfare. The land area had been relatively neglected until the last couple of years. This has speeded up, coupled with some work in the Army, some major work at DARPA, and some private industries who have been building some systems on their own with venture capital. There has not been much support from the government, although recently they have sold some part of their programs.

The Defense Advanced Projects Research Agency has what is called the Strategic Computing Program, not to be confused with the Strategic Defense Initiative. The Strategic Computing Program is the DOD answer to the fifth generation computer work that Japan has begun, the attempt to leapfrog the next generation computer technology and develop an intelligent machine with all kinds of user-friendly interfaces -- the ability for people to walk up to a computer and talk to it in natural language, have the computer able to learn, have the computer able to respond as if it were another person, only with greater memory and certain abilities that people don't have. This response has led to three demonstration projects associated with the Strategic Computing Program - three because there is one for each service, if you lump the Marines in with the Navy. The N- .rines have a Battle Management Program which is kind of an admiral in a box with a lot of expert systems and sensors to make all kinds of very rapid decisions in the context of a very, very high speed conflict such as what is called the outer air battle. We have lots of missiles and airplanes flying around and time is very, very short and the risks are very large.

The Air Force portion of that program is the Pilot's Associate, which involves developing a smart cockpit where the pilot can talk to the cockpit verbally and the cockpit can respond. It is not just simple voice synthesis, but with some understanding, and includes the ability to take sensor

information in and make decisions or even act autonomously under certain stringent conditions. This leads to the question of with such a smart airplane, what are you going to do with the pilot. This is something that has not been answered satisfactorily. Many people believe that it is more a political decision for the Air Force, than a really rational one. No one has become a general mucking around with unmanned air vehicles, and also flying $30 million high speed planes is fun, so it is not likely that the Air Force will get out of that business in the future with a great deal of ease, regardless of the technology.

The Army's part of the program is the Autonomous Land Vehicle that I will get into in a bit, and they also have some other programs on the ground - land vehicles, as well as in the air, the RPV, the AQUILA program. The Navy has water things, as well as air vehicles. They brought some of the Israeli RPV's. We also have smart cruise missiles for the Air Force and the Navy, so the jargon now should be not only "smart," but "brilliant."

Here are some quick pictures to show you what I am talking about. This is the AQUILA RPV, a remotely piloted vehicle, teleoperated as a link with the ground, although it does have some autonomous ability. This is a less fancy looking model that was built by the Israeli's and successfully flown in combat. This is a kamikaze-type bird. It has a seeker, a processor, it is launched in various ways, maybe out of a box like a round of ammunition. It goes off and hunts a target. It can do that through various degrees of intelligence, depending on what it is given in the way of processors. Here is a case of a vehicle homing in on an antenna on top of a truck and making a direct hit. You are talking about the ability to hit things on the head now with relatively small, cheap weapons. There are some important potentials here with respect to raising the nuclear threshold. Here are some more vehicles being built by Canada. One of the implications of this technology is that while it is sophisticated, it doesn't have to involve a great deal of money. It is a lot cheaper to develop and build these things than it is to make high performance manned aircraft or other kinds of manned systems. Therefore, almost any country in the world, except maybe the poorest, can get into this technology.

Here is a nominal mission profile for an attack drone. The vehicle is launched; it has long legs which gets into the problem of being able to get at the Soviet second echelon without worrying about acquisition necessarily. That is, if you have the crudest kind of acquisition, if you have a smart enough vehicle, it can do its own kind of searching. If it has sufficient endurance, then the target doesn't have to be within the basket that you send the vehicle out of, it can be somewhere else. If a countermeasure is attempted, the vehicle can go back, it can recover back into a loiter mode, another search pattern, and wait -- unlike a missile which would just hit the ground.

What is the advantage of these kinds of systems over existing systems? To begin with, if you have a manned system, it is expensive, it is large, it has limitations because of its weight and its size, it has to support people, it needs oxygen or shell protection. If you have an unmanned system, you can make it smaller because it doesn't have to accommodate a person or the life support system, it can be made cheaper, it can be made simpler to use, even while it is more sophisticated. It's like modern personal computers. They are relatively sophisticated, yet relatively easy to use because they are designed that way. The complexity is designed into the system, but is not reflected in the interaction with the user. Just so, unmanned weapon systems can be made so that they are user friendly

Here is a possible evolutionary sequence for these systems. We currently have teleoperators, RPV's and tows and the like. Somewhere in the next couple of years, relatively unintelligent robots will be getting into greater use -- cruise missiles currently exist. You can consider a cruise missile a robot weapon system. Ultimately there will be what most observers would call intelligent robots in the service doing a variety of tasks.

I would like to go over a couple of these programs in a little detail. The DARPA Strategic Computing Program is going to be looking at the application of expert systems, vision and voice, in its Autonomous Land Vehicle Project. Each year between now and 1990, there is a series of goals where the vehicle is going to be put through some paces to see how the technology is working. The first test was simply to have the vehicle drive on

a road and not go off. It sounds simple, but it hadn't been done. If it's an autonomous vehicle, it is not linked to anything and it has to be able to detect the edge of a road and not veer off of it. That test was successfully accomplished. Skipping the years to the end, what is wanted in 1990 is that a human being can go to this vehicle and give it an order as to where to go to do reconnaissance, let's say, or some other mission. The vehicle has its internal digitized terrain data base and a variety of sensors. It takes off and does an initial plan, using its sensors to avoid bumping into trees or falling into holes and to operate amongst other moving vehicles. It knows enough to take camouflage concealment or other protective measures from threats because it knows something about threats. It gets to where it is going, does its mission, and comes back. This is a test goal by 1990, and they want that all done by walking. This is a fairly ambitious part of the technology, but it has reached a certain level of progress. The laboratory vehicle is a hexapod, but the ultimate vehicle will be a quadropod. The reason it can move so fast even though it is on four legs is that each of the legs is eight feet tall. It is a very large, dinasaur-like creature.

The Army has its own research track which is different than the DARPA project because they want to evolve autonomy from a teleoperator as technology improves. They start with 100% man in the loop and remove the person a little bit at a time, and ultimately 10 or 20 years from now, you'll have autonomy. The DARPA project is attempting to get that right off.

The Navy has its own underwater work where they are looking to build intelligent submarines, unmanned submarines. The Marine Corps has this gizmo that is a teleoperated, anthropomorphic vehicle, the one that I showed you at the first that looked like Darth Vader. It is not an autonomous robot at this point, although that is the ultimate goal. Now it involves a man in the loop 100% of the time to provide a sense of remote presence to the human operator. The human being sees in stereo and hears binaurally, and therefore very rapidly gets the impression, the feeling that he is at the location where the robot is. There is a link that could be radio, but in the demo it is a fiber optic link, but the stereo vision and hearing gives the person three dimensional spatial indication. This thing has been put in a vehicle and driven the vehicle around, and been used in place of a person in this vehicle.

Here's the six legged ODEX walker. It is not an intelligent machine, although it can take a variety of positions. Basically, each leg has its own little microprocessor, but the current version requires a man in the loop to indicate general direction and certain basic commands. Then the microprocessors that are controlled by a central processor on board then works out the algorithms on how to move the legs and the individual articulators, but the ultimate goal is to have an autonomous vehicle.

There is another land vehicle built by a company called the Robot Defense Systems which has what amounts to a list machine on board, six on-board 32-bit micro-processors. I have a video tape of this vehicle in action that I can show.

The effects of all of this in the future are going to be enormous. If you take the analogy with the automobile and look at it from the technology impact point of view, the first order effects are linear extrapolations of the ability of the current technology. So if you go from a horse and buggy to a automobile, it's faster, more convenient, or whatever. You can draw those same kinds of conclusions for robotic systems -- more accurate and more flexible weapons, faster and cheaper weapons manufacture, improved C^3I, and replacement of humans in hazardous tasks. Second order effects are displaced in time from first order effects and involve second order changes, changes that are non-linear. Those are tougher to see. In the case of the automobile, they might correspond to the growth of new industries, the cement industry, the growth of suburbs, changes in social patterns. Those things are maybe decades down stream. Of the second order effects of robotics, the nonnuclear deterrent one I think is very important. The reason that you have tactical nuclear weapons in Europe, most of which consist of 155 mm artillery rounds, is that they give you a big bang for the buck. A cheap way to knock out a lot of tanks at one shot if you don't have a lot of tanks to do that. Conventional weapons in the past have not been able to kill tanks or other targets efficiently. If you have small, smart, cheap things like kamikaze drones, land vehicles, and you have them in sufficient quantities, there is a potential for these kinds of things to replace nuclear weapons in Europe. If you have a smart rock that can hit a person on the head just right, you don't

need a nuclear explosion. You also get rid of the use them or lose them possibilities, and you therefore raise the nuclear threshold.

In the training areas, the kinds of people involved, the kinds of skills, the numbers of people involved due to the introduction of robotic technology are going to be profoundly affected. I will point out that it is not clear to me whether these kinds of systems will create a more likely or less likely possibility of war. It depends on your initial assumptions. It might be that you have a kind of potlatch warfare where each side is throwing vast numbers of machines that add up to lots of dollars. People aren't getting killed very much, but the first one who goes broke is the loser. There is also a blurring between tactical and strategic warfare. If you have a machine that you can send thousands of miles away and specify that you want it to go to a particular corner in Moscow and do something, this overlaps with your strategic ability, even though the machine itself is small and relatively inexpensive.

Some of the research issues that I see include the variety of things that have to be done in the sub-technologies, the mechanical systems, the processors, the software associated with the processors in particular, the sensor systems in all of the wave lengths, the control systems that get involved with the software of how these things operate, the architectures, the man/machine interfaces and so on.

You have a lot of potential impacts in the training area if you are training the structure of the military. Robotics can be used on a first order effect as a training aid for teaching human beings. You can have the equivalent of a computer teaching machine, only it is a robot that can manipulate objects like maybe take apart an engine or do other things and act as an instructor, maybe on a one-to one basis. You also have to be able to train the robots. The robots are going to be doing things in the field, not only as weapon systems, but perhaps also as cooks and bottle washers, medics or whatever. The robots themselves are going to have to be trained. It is quite possible by the time frame we are talking about that you will have machines that can learn, using any kind of reasonable definition of the word. They can be exposed to situations and make inferences and go through an

inductive process based on their own experience. It would be just like people learn, and it might be on an equivalent time frame.

All of the impacts, then, involve people and machines in the field exercise, how people and machines are going to work together, the combat exercises and simulations can be very realistic, you can actually shoot at things that look like people and behave in a similar way but don't necessarily get killed. It seems to me, also, that training cost and time can be reduced significantly by providing one-on-one instruction, by providing very realistic scenarios with vivid training experiences.

The support structure for all of this -- the vendors, the people involved -- are going to have to change in some way, as well. They may be different, or they may have to learn new skills. The indirect impacts would also involve new skill categories of the people that you are actually training; you are going to train people to be robot operators. This will involve a curriculum for doing that. The kinds of people and numbers of people you are going to be training are going to be different. The structures of the combat units, as well as the structures of the training organizations, may be radically different than it is now.

Some of the key issues involved include the people who have interests and careers tied up with what is there now, whether it is a training system or a combat system. That is something that is going to have to be dealt with. We will need a determination of the value of the robotics in the training program as a training program, and the value ultimately of the robotics and the training program to combat efficiency and effectiveness. There will be a need to design the total system in terms of the people and robots involved, and the interactions between the two.

In terms of education and training research issues, there is always the basic issue of funding, the money to pay for all this. To what extent should the people involved in training research be chipping in on the technology development, so far as it could impact on training? The ability to use some off-the-shelf technology is an issue, to buy the pieces and integrate them, rather than doing basic research and technology. You have to worry about

training the machines or human beings who are the trainers, and we need to design the appropriate kinds of facilities for training, which includes exercises. There are organizational issues, and then ultimately the need to develop some criteria for both the people and machines doing the training and those receiving the training, in terms of intellectual, psychological, and physical requirements.

Last, there are some basic issues in the whole field of combat robotics. There has been in the past a reluctance and inertia because of the psychological as well as the rational reasons why people do not want to give up things. There is also a rational resistance to technology; new things often fail. There has to be some level of reasonable caution. However, there are also the usual political and cultural inter service problems involving organizations working together or competing for dominance in the various pieces of the program. We also currently have the lack of a design on how to integrate these systems with existing systems, with people, in some appropriate way. And, overall, up until now this entire area has not really gotten the top-down kind of support like, say, the Strategic Defense Initiative has received, and it has all been a question of little pockets of interest and technology and money bubbling up in the services, and some of them evaporate very rapidly.

Currently, there is sufficient support so that I think it is finally real, it is going to go somewhere. Sometime between now and the year 2100, you are going to find these things in vast quantities permeating the services. The question would be when, between now and then, and my own guess is that in the next five or ten years you are going to see the first wave of systems in there. Within 20 to 25 years, lots and lots of things will be there, and they will be things that you can call "intelligent." I think the revolution here is analogous to the industrial revolution, in that the industrial revolution overturned the existing technologies and practices very rapidly, but continued on for at least a century after its initiation. I think the robotic revolution is going to be comparable. Within five to ten years, there will be major changes in society due to robotics, not only in the military, but society in general. I think this is going to continue for maybe a century before it levels off to some extent in the technology and the application.

Baker: We can now take questions for any of the first three speakers.

Question (Perez): Dr. Gazzaniga, I wonder if you have in mind a set of research issues in the areas of memory and training that needs to be addressed in the neurobiological area?

Gazzaniga: I think there are, and I think they work at all levels. I think there is a new molecular neurobiology that is going to tell us which parts of the brain are more active in various kinds of memory tasks, and that is going to capitalize on the new molecular neurobiology of using monoclonal antibodies, recombinant DNA technology. There is just no question that is going to go ahead. But in some sense, all that is going to do is tell us, to use a metaphor, all the players in the game. I think what is going to happen to make sense out of that is going to be a general scientific problem, and those trained in artificial intelligence and cognitive science are going to come in and take those elements and see how they are orchestrated in some systemic way to understand psychological memory. I don't think that the neurobiologists who come up with the actual neural elements and mapping relations and neuropharmocological substances will be the ones to construct the theory of how memory works. I think people with more formal training will take that knowledge and come in and actually construct the model. In fact, NAR and others are working on these kinds of problems right now, but with very limited neurobiological strength. They are just sort of doing it ad hoc and having fun with it, and the biological realities of the model are virtually nonexistent. But I think those things will converge in the future. Very practically, I think the people who are interested in agents to manipulate the attentional system are going to find substances that will, in fact, assist memory in the foreseeable future.

Comment (McAlear): I would like to comment on Dr. Finkelstein's talk with regard to one aspect. Apparently the different services have different programs and expectations for robotization. Certainly, the leader in this, as far as all the money is concerned and the technical objectives, would be SDI. This is a major problem - being able to get enough information through-put so you can make all the right decisions in about 20 minutes. That's a tremendous technical achievement. If this were applied to the other services, if there

was that capability, then certainly the kinds of robots envisioned as state of the art could be vastly beyond those that are presently projected. I think this may be one of the major problems - the need for some direction from the top that says that you have to keep up with the real technical expectations of the SDI in order to achieve what is technically possible, because if we don't, somebody else will. I don't believe that the Soviets are going to allow us the luxury of waiting until 2010 to use the kinds of systems that are technically possible to achieve well before that.

Finkelstein: Well, from one perspective, the SDI as a system is one giant robot.

Baker: We will terminate the discussion now, and reconvene at 1:30.

Baker: Our next speaker is Dr. George A. Miller, who is the James S. McDonnell Distinguished Professor of Psychology at Princeton University. His topic is Some Psychological Perspectives on the Year 2010. Dr. Miller.

Miller: I wrote too much. As a professor, I profess, and that leads to lots of words. Last night I tried to cut it, and this morning, I decided I would just throw the first half of it away. The first half was to sort of fill you in on the current state of cognitive psychology, and I think I will just piggyback on Professor Gazzaniga's elegant presentation this morning and say that's what I wish the state of cognitive psychology were, but more broadly than at Cornell Medical School.

I'm interested in what's happening here at an intersection between psychology and technology because, in the history of my field, the conception that people have had of what the mind was and how it worked reflected very much the conceptions they had of the machines of the day, the mechanisms of the day. Whether it was Plato's shadows on the cave wall, or the connections of the telephone system that modeled the brain, or whether it was reflexes, or what have you, the theories that psychologists have been inspired by have come very heavily from the theories of what machines can be and do. As our

conceptions of modern machines get very much more intelligent - I was amazed to hear that just being able to put that many elements on one chip was going to make some intelligence emerge, but if that is the case, at least it will remove one of the limitations that has kept intelligence from emerging. At any rate, I keep looking over my shoulder like Satchel Paige, seeing if anything is catching up. With those robots tromping up, I'm going to run faster.

I can give you a summary of the various topics, and rather than go into each one, I'll just indicate that usually the psychology of cognition is divided into a bunch of sub-topics - perception, attention, memory, imagery, thought, and language. Professor Gazzaniga talked about perception, attention, memory, and didn't get to the other things. I'll say a little bit about them. Each one of these fields is a specialty in psychology. They have their own journals, their own meetings, they hire their own people, they talk to each other, and they can't understand one another. It's a very unfortunate situation in my field; when you come to the area of general cognition, we just don't have a good theory for integrating all of this. This is after maybe 30 years now of promises from people interested in cognitive simulation and artificial intelligence that the systems theory is really going to integrate it all. It's certainly true that the only people who worry about how all these different mental functions are going to be put together are, by and large, people who are trying to simulate organisms that will do intelligent things. The actual state of cognitive psychology I think is unfortunate, and we are in need of some over-arching insight like Newton's laws of motion were for physics or Darwin's theory was for biology. We need some integrative concept for psychology.

I want to say a little bit about psychometrics, because it also is in a difficult state at the moment. My friends at the Educational Testing Service tell me in moments of unpublishable frankness that the multiple-choice question has gone about as far as it can go. They are beginning to look for new ways of testing intelligence or mental ability. One of the things they have developed, at the request of the military as a matter of fact, is the computer-given test. Fairly recently, Fred Lord really looked into this question of how you could use a computer to give a better test, and the

broad range tailored test does seem to be much more efficient and much more pleasant for the subjects to take. That's about where the cutting edge of psychometrics is at the present time. Anything more complicated than that remains for the future, and they are worried about it for obvious reasons. One of the things that is wrong is that you have to have a very large pool of items for the program to select from, and ever since they have had to declare their pool of items open to the general public, the idea of having that many items has been intimidating. Obviously, in times of difficulty like the present, intelligence is at a premium. Psychometric techniques for recognizing it and computer based methods for nurturing it, and an underlying base of scientific knowledge on which to build further cogitive technology, are also at a premium.

In the military, psychological theory and methodology has contributed to selection and training and communication, but the people in this room know far more about that than I do, so I will not belabor the potential significant advances. Instead, I have thought a bit about if we could develop supernormal communication. It seems to me to be a possibility worth thinking about. This is very speculative, but I think it is interesting to consider the possibility that we might develop a reliable psychotechnology for changing beliefs in predictable ways. Imagine what we could do if we had such a thing. After instilling beliefs in the value of human reason, we might instill beliefs that war is impossible, that altruism is better than self preservation. We might even convince people that this is the best of all possible worlds, and that Xerox knows how to make things in addition to copiers. If psychological science could provide dependable techniques to impart particular techniques to everyone, then I think the whole character of social planning, social control, the whole basis on which our social, economic, and political lives are regulated could be molded to suit whoever controlled those techniques.

We do have a remarkable technique for changing people's beliefs. It exists at the present time. Psychologists didn't invent it. It's called language, and it's used in education and argument. It has always been our most effective tool for shaping belief systems. It is used by parents, educators, advertisers, politicians. Huge portions of belief systems of the average citizen have been created not by their personal experience, but by

words and pictures. It's true that we can make the changes, but they are not always predictable. It's unreliability seems to arise from its universality. One person's linguistic persuasions have to compete with everybody else's persuasions. It is only when some great demagogue arises that the power of language becomes apparent, and large groups and whole nations can be led into madness. To guard against this abuse of the power of language, free nations go to great lengths to ensure freedom of speech so that many different messages are heard and the populace remains in perpetual confusion. Conversely, in order to increase the impact of particular messages, a dictator tries to eliminate the competing communication.

There has been a lot of psychological research conducted to determine the variables that will affect the persuasiveness of linguistic messages. Advertising agencies have made very good use of the result. The techniques that have been analyzed carefully generally involve pairing the message with some kind of reward for attending to it. There have been good results from these techniques, but there has always been the hope that something more effective could be discovered. I think it is conceivable that a method of communication conferring persuasive powers far greater than we are accustomed to in every day life might be discovered in the next 25 years. The phenomena of animal magnetism, as they were then called, were known a long time before Mesmer discovered how to induce them at will. In the same way, we are now familiar with instances of persuasiveness that far outrun normal expectations, and the possibility of discovering how to produce such effects shouldn't be dismissed too lightly.

What would such a supernormal communication look like? If it resembled hypnotism, some plausible guesses could be made about it. For example, individual differences in susceptibility to the technique might be expected. Voluntary resistance might work initially, but after a first induction, a subject could be persuaded that further resistance was useless. The method might be useful in treating phobias and in extinguishing unwanted habits, relieving some kinds of pain, as well as in instilling general attitudes such as respect for authority or disapproval of deception, general optimism, or whatever. Subjects wouldn't feel that they were in any unusual psychological state; that is, their instilled thoughts or actions would follow as normal

consequences of their revised belief system. The likelihood of our discovering techniques of supernormal persuasion that might be used in interpersonal communication is extremely small, but the potential consequences are so explosive that the possibility deserves some serious attention. If, for example, it could operate in any situation, even over radio or television, then the social implications would be far more dangerous than if, say, it was effective only after the administration of some particular drug. The most plausible mode of operation would resemble hypnosis, where the cooperation of the recipient plays an important role. If cooperation were not necessary, the technique might be extremely useful for interrogating suspected criminals or enemy intelligence agents.

That was my speculation, and I would like to return to my main theme now, which was trying to project psychology into the future where I find that some of the most important developments promise to come not from within psychology itself, but from related fields -- particularly artificial intelligence. In order to introduce these ideas into the discussion, I want to assume certain, I believe, plausible developments in information technology and then consider changes in education and training that those developments could make possible. I'm not sure, given what I have heard this morning, that I can think 25 years ahead, but my experience has been that if I think something can happen in 10 years, then probably it will happen in 25. I will work on that basis, in spite of warnings to the contrary.

Let's assume that computers are going to be directly linked to communication networks so that they talk directly the way we use telephones today. I assume that Bell put up with the divestiture for good reasons. The advantage of this kind of a network is that any individual computer connected to it will have immediate access to services and information that could increase its virtual size, and hence its value to its user, by orders or magnitude.

The technological assumptions that seem to me important for psychology are, first of all, the national network and its effects on natural language interfaces, and then some things that are coming along in parallel processing. As far as the national networks are concerned, I think that most

of the parts that are needed to create a system like that already exist. Of course, computers require far greater band width and than human voice, but fiber optic technology is already with us. That gives us gigabites per second over long distances for affordable costs, so anything you now have on local area networks will soon be available on non-local networks - national or even world-wide. Putting all that together is not a trivial task, but I assume it is going to be accomplished.

Two aspects of this development lead to psychological questions of considerable interest to me. First, how will an individual user gain access to this system, and what kinds of interfaces are going to be available? The second question, not unrelated to the first, is what special skills are going to be required to use it effectively? No single interface is going to be optimal for every use, but it seems to me highly likely that many users, particularly if this is going to be supported by businesses, will want to interact with this system in something reasonably close to natural language. By the year 2000, that kind of interaction should certainly be feasible. As I'm sure you know, one very active branch of artificial intelligence explores questions of natural language generation and comprehension. Language processing systems already exist that can hold acceptable conversations on strictly limited topics. Considerable success has rewarded efforts to deal with the syntactic aspect of language. The conventions that guide conversational interaction are being cleverly incorporated into these systems. What limits them most is their stupidity.

Before such systems as these are going to be generally useful, at least three very difficult problems are going to have to be solved. First, they must have access to a large, general purpose knowledge base. Second, they have to be able to deal with an enormous vocabulary, and third, they have to be able to reason in ways that human users will find familiar. Other problems like automatic speech recognition and digital processing of images could be added to the list, but the first three are critical. Problem one should be solved by attaching the system to the network. There will be an enormous amount of knowledge available to everyone. But in order to understand that knowledge, the machine has to be able to process language in the way that human beings do. One of the big limitations of the existing language

comprehension systems is that they have maybe 1,000 words in them. That's all they need for the demonstrations. Obviously, if you are going to read anything that you might encounter in a world network, you are going to need on the order of 250,000 or half a million lexical entries. Since standard dictionaries contain only about half the words that are printed in newspapers, they leave out all the proper nouns, place names, people, that sort of thing, perhaps another 250,000 entries would be needed for those. That's large but it is certainly possible in principle.

One of the items of psychological interest would be how to organize such a thing. All of that information doesn't get into your head in just an alphabetical listing. It is highly organized knowledge, one of the high roads into your perception of what the world is and how it is organized. Studying the organization of lexical information is like studying your ideas that are so important to you that you have actually lexiconized them so that you can talk to others about it. Those are important ideas, and they are well worth studying. We estimated at Princeton that if we put in about 10,000 semantic primitives, and compact formulas to derive the rest of the meanings of the lexical entries, that that might be sufficient. Then we would want to have some sort of a geo-political model to provide an efficient organization for the many proper nouns. Psycholinguistic research on the organization of this kind of knowledge and the order in which it is normally acquired by children would guide, I think, the discovery of better ways to organize lexical memory in machines, since in the area of language, the human being is the only successful instance that we have available to imitate.

The third problem, the ability to reason as people do, is probably the most difficult of the three. It's not likely to be solved by any simple, single insight. In addition to the huge corpus of knowledge that will be available via the network, the user's system has to command a large body of information about how to search the network, what topics the user is interested in, results from previous searches, information about language comprehension and generation, conversational conventions, various kinds of abstracting procedures, how to infer user's goals and subgoals in a conversation, the difference between relevant and merely valid inferences, how to incorporate the consequences of changing the data base from which

inferences are drawn, when to abandon things that you believed but now believe to be false; all these sorts of things have to be solved. Various parts of this kind of reasoning system are currently being studied in several AI laboratories, and some thought has been given to how to integrate it all into a coherent computer architecture. However, here again, knowledge of human performance has to guide the discovery of machine heuristics that will be able to appreciate what people leave unsaid, will know when to be literal and when not to be, and will not bore users with inferences that are either incomprehensibly obscure or boringly obvious. Getting the right level for a machine-friendly reasoner is not at all easy.

Other lines of research that will contribute to the usefulness and appeal of such large networks will be progress in speech synthesis and recognition so that users need not be limited to manual input. Rapid advances in the creation, transmission, and storage of high quality images are going on. The ability to integrate such pictures, both still and moving, with written language or synthesized speech, is a technology that is already moving forward rapidly. While it is not essential for the acceptance of the national network that I think is coming, it could have very important educational applications.

In any case, it is reasonably certain, given support from both industry and government, that computer networks will be in place by 2010, and that large numbers of users will have access to such information utilities by highly intelligent work stations capable of natural language processing and inferencing.

Another important technological advance is going to be the emergence of parallel processing in computers. I think at the present time in that branch of computer science called artificial intelligence there is an increasing amount of interest in the possibility of parallel processing. That is a technological advance that has been stimulated by work in cognitive psychology and the related neurophysiology. The fact is that the way the brain works is clearly parallel. There is also a lot of evidence that the way you retrieve information from memory must be parallel or multi-addressable. One of the more interesting things about verbal knowledge to me is that as you acquire more of it, it doesn't take longer to think of what you know. Ordinarily, the

more things you put into store, the longer it takes to find something in that store, but it does not take an adult who knows a large number of words longer to think of "retrieval" than it takes a child who knows far fewer.

It seems like a lot of fuss, but there are actually only a hand full of people out there working on parallel processing. It started just five years back, perhaps, with Haupfield's proposals, picked up by Henton, Zanowski, Feldman. Since I can think of a half dozen, maybe there are a dozen who are actively working at this, and yet suddenly, almost in the last six months, every lab I go to has someone in the back closet working on a parallel model of something or other. It has become quite striking, and I think there is going to be a very rapid increase in this. If we do get the really high density devices that are coming down the road, I hope we will find some way to program those things in parallel so that we can take advantage of it for perception and searching large bodies of data rapidly.

The implications of parallel processing are going to affect the study of perception. It's interesting to see when you ask these fellows why they don't like a Cray if they want all that computing, they say that parallel processing is the way the eye did it. Or the way the brain has stored its knowledge is in parallel processing, and that's the way the brain resists all of the noise that it is constantly operating in. If you get that kind of noise in a serial machine, the thing doesn't work at all. If you have ever tried to use a computer over a telephone line more than a hundred miles long, you know how debilitating just a little bit of noise can be.

So, we are going toward parallel processing, and that is going to teach us a great deal of how the brain is organized at both the neurological and psychological level. It's a systems problem, as Dr. Gazzaniga was pointing out. Knowing what the parts are or who the players are in the brain is not going to tell us how it works as a system. We have to have this higher level of theory. The theorists have finally decided to bite the bullet; clearly, it is parallel. The serial machine is not right. So, by 25 years from now, we will have made 10 year's of progress.

There are implications for education and training that interest me. If we have machines that handle language easily, there should be really significant developments in our educational technology. In institutions of higher education, for example, they are beginning to try just giving students access to the basic data, either in its natural state or edited to be more comprehensible for pedagogic purposes. Students of economics or sociology will be given direct access to census data or whatever, and taught techniques for analyzing those data in various ways, and will probably develop their own techniques. Students of the experimental sciences will be able to see data from actual experiments and follow in detail the inferences based on it. With a modest degree of expertness built into the system, such instruction will occur in an interactive mode that will involve natural language, as well as statistical or mathematical operation. The techniques of data analysis used at the frontiers of science will be available for classroom instruction by 2010.

I don't think we'll have classrooms by 2010. Have you ever stood in front of a classroom with 30 computers in it? The only way I could get their attention was if my face appeared on the screens in front of them. Here they are hunched over, typing away; trying to lecture to a classroom like that is madness. You can't. The only thing you can do is to have two classes; one in an ordinary classroom where you get your message across, then you turn them loose in a computerized classroom. I really do think that classrooms are going to disappear. With the intelligent work stations that should be available in 2010, individualized instruction and record keeping should be possible without teacher's direct intervention. At that point, no one will remember why students had to participate in this interaction at the same time and place.

Intelligent tutoring systems already offer individualized instruction, and many of the advantages of the human tutor. At the present time, most of those systems are running on menus. I've even heard it argued that menus are better because they constrain the students to the subject. But I bet you that if we have a good language understanding system, those menus will disappear pretty fast. The availability of systems that understand language would enable a synthetic tutor to approximate the human tutor even more closely. At present,

these systems concentrate on subjects like mathematics or programming languages. I think the ability to process natural language would greatly broaden the applicability of those techniques.

I have sort of imagined a scenario where students sign up for a course and they are assigned the textbook they have to study to pass an examination. The text is retrieved electronically, not bought at the book store, along with all the primary sources that it refers to and any supporting survey or archival data that are needed. The student begins reading and then he interrupts to ask a question, and the system answers. A more complicated question maybe stumps the machine, so it sends a message to a professor who responds. This interaction goes on until the student decides he is ready to take the test, and the machine gives him the test. Perhaps the system discusses the student's errors with him on the test, and after several sessions, he decides he has mastered the subject. You could write that kind of scenario for almost any academic or practical subject. The critical point is that a relatively modest increment in the intelligence of a work station, the kind of increment that educators should inherit as a spinoff of predictable advances in information technology, is going to open up exciting possibilities for computer aided instruction. The only skill that the kid has to have is the ability to type. I'm shocked when I occasionally get a Princeton undergraduate who doesn't know how to type. Society is having less and less use for illiterate laborers as the information revolution continues, so there are very strong reasons to ensure that appropriate instruction in these basic skills is available to everyone.

More advanced instructional materials will deal increasingly with problem solving, rather than with information that the student is expected to be able to reproduce. Memory for content will be increasingly externalized and replaced in personal memory by the procedures used to gain access to that part of externalized memory that is needed for the task. Creative use of information technology that will be available will probably require relatively sophisticated knowledge of how the system works, knowledge that will have to be made available to novices by the system itself.

You could also write a similar scenario for psychometric measurement, new horizons for testing in which you essentially hold a conversation with the person and evaluate whether they have dealt with a simple interaction with the machine intelligently or not. That is quite different from the sort of multiple choice question, or even the computerized multiple choice question and answer thing that we now use.

Question (Henderson): Do you think that the gap between the information rich and the information poor both in the domestic U.S. and the rest of the world will continue to increase?

Miller: I think in terms of the rest of the world, it probably will. One of the reasons I got interested in all of this was a remark made to me by a black mother in West Palo Alto when I was visiting a school that had installed computers. I asked her if she liked those things, and she said, "Yes." When I asked here why, she said "Because they are color blind." It occurred to me that if we could get the machines working all right, they really are color blind, and they don't even have a nose to see if you have washed. Anyone who can work a keyboard can use them. My whole hope is that this is going to open up the doors leading into knowledge sources. I have a long talk I give about the failure of the American school system to do what it should have done. Mostly, it was used to keep the poor in their place, because we needed lots of unskilled laborers. If you failed school, you went to work to build the railroads and dig the ditches and do the hard work that it took to build America. Starting along in the 20's and 30's and 40's, and certainly by the end of World War II, we began to have something the economists called the information revolution where people who can't read and write are a burden on society. One of the things we have to do if we are going to have a country that is working as an integrated unit and not split wide open is to provide the kind of entry into the information technology that people need. I think it is possible and might actually be easier with machines than with human teachers in the classroom.

Henderson: But we are going to have to provide the money for them to buy the machines, aren't we?

Miller: What we are doing now is since they can't get a job, we put them on welfare. We have this tremendous burden coming around in that way. On the other hand, if they were tax payers, we could get it from them instead of having to give to them.

Baker: I am going to have to play the role of bad guy to keep us on the time track. I hope we can continue these discussions later or this evening at dinner. I would like to make one observation. I recently read an article flying back on a plane that threw me in terms of what George just said about super messages and as they come across the TV. People in the military that one gets interested in are ones that come in at age 18, and if you look at the statistics, a person at age 18 will have spent more time watching TV than they will have spent cumulatively in school.

Moving on to our next topic on our agenda, we see that it is Engineering Anomalies Research: Consciousness, Creativity, and the Horizons of High Technology, presented by Dr. Robert Jahn and Brenda Dunne of Princeton University. Dr. Jahn is the Dean of the School of Engineering/Applied Science and Ms. Dunne is the Manager of the Engineering Anomalies Research Laboratory. Dr. Jahn's areas of research are advanced aerospace propulsion systems, plasmadynamics, ionization phenomena and engineering anomalies. I will leave it to them to decide which one will speak first.

Jahn: Brenda's enthusiasm for this project is so high and her vocabulary, so limitless, that I never get in a word in sideways when we are back at the laboratory. When we travel to make presentations, I pull rank on her and insist on making the first part of the presentation, but I guarantee that you will hear much more from her later on in the question period.

I'm sure many of you have seen the light beer commercials on television usually associated with the sports shows where a bunch of over-the-hill athletes sit around arguing about whether a beer tastes great or is less filling. When all of the shouting dies away, one of the least competent and most lovable of all major league baseball players, Marvelous Marv Throneberry, sits alone in the corner on a stool, shaking his head sadly and saying, "I

don't know why they asked me to do this commercial." That was more or less the reaction I had when Kerm called and asked me to make a presentation in this particular forum, and I must say that the talks we have heard so far today have not done much to relieve my anxiety. It's further exacerbated by the thought of trying to communicate anything of the substance of our program in such a contentious field as this in now what must amount to 19 minutes. But I shall try, dashing lightly over the waves. I would suggest that any of you who are seriously interested in the topic might like to look through our written paper or the viewgraph off-print copies that we brought along with us, or perhaps some of our more extensive publications that Brenda can give you.

The topic is engineering anomalies research and, as its name implies, it is an attempt to examine the possible vulnerability of various physical devices, systems, and processes to anomalous influences of human consciousness. It does indeed attempt an engineering perspective on this topic, selecting those particular aspects that seem to have immediate relevance to the practice of high technology, and perhaps some longer term relevance, as well. Using topics that seem to lend themselves a little better to more controlled laboratory study, we try to bring to bear state of the art engineering equipment and techniques in this study. We concern ourselves primarily with the physical and technical parameters, rather than with the psychological or physiological correlates that others have been looking at.

In our particular program, all of the data are generated by what we call "common operators," folks like you and I who claim no particular abilities for this sort of thing. They are all anonymous and all uncompensated, and we have tried to speak only to the professional communities so far. We have a very rigid media policy, and try to keep the enterprise on as high an academic plane as possible. The program, like all of Gaul, is divided into three parts that are hopefully somewhat symbiotic. The first relates to anomalies that can be discerned in the operation of various physical systems and devices, but correlated with particular operators of those devices. The second goes by the name of precognitive remote perception, and really deals with the acquisition of information about remote locations by some anomalous means. Thirdly, we have made some attempts to develop a theoretical model that will be helpful in correlating the data and in developing more effective experiments, and

eventually in explicating the phenomena on more fundamental grounds. I would like to dash through those three portions in succession.

Part 1 involves a number of table-top experiments involving random physical processes of some sort. These processes may be mechanical or electrical or optical or thermal in nature, but they are implemented in machinery that has certain common features. We try very hard to establish baseline distributions that are incontrovertible. We take considerable care to protect against artifacts that could confound the results. All of our data are collected on-line and recorded in redundant modes. The operators of these machines are provided with various types of feedback, immediate optical feedback usually when they are performing the experiment, and then we have access to the results as they emerge. Perhaps most importantly, we rigidly enforce what we call the tri polar protocol, which means data are generated in three concurrent streams, one with the operator attempting to distort the output of the device in one pre-stated direction; the second, an attempt to distort similarly in the other direction; and finally, an attempt to do nothing, to take a baseline. And only where clearly separable achievements are found in those three parallel strings of data do we regard an affect as having been observed.

I'll illustrate this class of experiment in the context of one particular device that you can regard as more or less prototypical of the several others we have going. This is a so called random event generator. It is based upon a commercial micro-electronic noise diode that comes in a package and produces very high frequency noise. It is then processed in the circuity to provide a random string of alternating positive and negative bits suitable for counting. The machine does indeed count them according to some dial instructions that have been set on it. For example, we tell it to make 200 counts of all the positive pulses or 2,000 counts of negative pulses, or whatever, and these are then displayed by LED's for the operator to attempt the experiment. As I said, we take care to baseline these devices as completely as possible.

The top graph shows a super position of baseline data taken by one of our operators in the course of a experiment on the theoretical calculation of this

machine. This is simply the Gaussian approximation to the binomial computation that's appropriate for this particular binary device. In this case, the machine was set to take 200 bits and to record the number that corresponded to the plus/minus, plus/minus in its regularly alternating sequence. This was done 23,000 times, so we are processing quite a large number of bits rather rapidly, and we are giving you here a frequency of count distribution that was actually achieved. The mean sitting there at 100 where you would like it to, the standard deviation and all of the higher moments conforming rather nicely to the theoretical expectation.

Now, when the operator of this device, either on instruction or on volition, attempts to shift the number of counts to a higher value, the data are those seen in the middle with the solid spots. When attempting to go to lower numbers of counts, what you see is the distribution of open circles. You put that raw data into the computer and tell it to give you the best fit, and you see something like the bottom. This is more or less prototypical of the sort of thing we see in this class of experiment. A very slight shift in the mean, but otherwise preserving the Gaussian distribution of the baseline. That effect looks rather tiny, but if you continue doing the experiment, it turns out that the operator is capable of repeating that effect on a statistical basis for at least a long period of time.

Here we have plotted what we call a cumulative deviation graph. It simply is keeping score of the accumulated displacement from the theoretical mean that this operator is achieving over a very large number of trials. We are now up to some 12,000 trials. The dashed line along the center would be the theoretical mean; the baseline performance is seen here meandering stochastically about that. The upper wiggly line is the accumulated attempts to go to higher numbers of counts and the lower line attempts to go to lower numbers of accounts. You can see that although there is this same sort of stochastic variations, they are now superimposed upon a more or less linear trend that takes the deviation from the mean to higher and higher total values as the number of trials compound. The dashed parabolas are simply the low side of the .05 probability against chance envelope, and the terminal probability of getting that sort of deviation by chance can be computed. Those numbers are on the right. You can see the likelihood of that deviation

in the positive direction is less than one part per thousand; the likelihood of the negative deviation, something like a few parts per million; and the total likelihood of seeing that separation by chance is an astronomical figure, a few parts per billion.

That particular performance is characteristic of that particular operator. When you do experiments with other operators, you see different types of results. In fact, they are so characteristic of the operator, that we refer to them as signatures of achievement. Here, for example, an operator succeeds in the attempts to go high, and also later on, in the attempts to go low, much like our first operator. But this third operator, on the other hand, has only a marginally successful performance in attempting to go high, and can do nothing but baseline when attempting to go low. Here is another operator who does just the reverse; reasonably well attempting to go low; not so when attempting to go high. I could show you a large succession of these - operators who just don't achieve in any direction; operators that invert, that go high when they are trying to go low or the reverse -- but the characteristic of their signature is an enduring thing, and therefore, we think indicative of some interaction between the operator and the particular machine.

If I collect all the terminal scores, and plot the frequency count of those scores in histograms, you see something like the following. For all of the PK+ data, and we are talking about 22 separate operators over 60 very long series of experiments, the histogram distribution is as shown. The solid line is the theoretical expectation and, as you can see, the population has been shifted noticeably to the right. Similarly, the PK- histogram is shifted similarly to the left. Of additional interest here, however, is that while all of the baseline trials taken by these operators in the tri-polar protocol have the mean at the expected location, namely the theoretical value, there is a standard deviation that is considerably smaller. In fact, there are no scores at all recorded out on the tails of the anticipated distribution, indicating that although the operator is addressing himself to the task of not interacting and taking a baseline, something appears to be happening, perhaps at a subconscious level, to constrain the distribution of scores. Whatever the effect is, it may have a subconscious or unconscious component to it.

Another curious property that I won't attempt to explain is that if you recombine all of those PK+, PK- and baseline attempts into one grand histogram of scores, it virtually reconstructs the theoretical chance distribution again. It is almost as if the distribution of chance expectations of these scores is being sorted to the high and low side and into the middle, simply by the intentions of going high or low.

Although these are clearly operator specific, operator related phenomena, whatever they are, if you combine all of our operators into one grand data base, the cumulative deviation graph still shows a high level of significance, much like we saw for our first operator. The likelihood of this total data base being split this far by chance is on the order of a few parts per hundred thousand.

There is one other curious feature about this class of experiments. Although it is operator-specific, and in some cases specific to the particular circumstances of the experiment, it seems not to be at all specific to the device involved. I don't have time to develop the other experiments for you, but these are similar, cumulative deviation graphs for three different devices. The same operator who worked on the REG machine also used a totally different noise source, in fact a programmed pseudo-random source. Another machine is macroscopic in size and involves 9,000 marbles trickling down through a batch of pegs and a distribution of bins at the bottom. Note the similarities in the signature between these three quite categorically different pieces of equipment. Higher achievements on the PK- efforts; less so on the PK+; baselines where they belong, and even some characteristic lumps appearing more or less at the same point in the history of the experiment.

If I were to summarize all of our category 1 data of this sort, we find that the results are very much indicative of the individual operator. There are some secondary dependencies on how rapidly we count or whether the operator is told which direction to achieve or they self-select which direction they want to try, or whether the machine is running automatically or they push a button to initiate the trials. However, there is very little specific dependence on the machine involved. Overall, we find that about a

quarter of our individual operator data bases exceed chance significance. The overall data base is significant also at about this level.

Part 2 of our program is called precognitive remote perception. The experimental protocol is fairly simple. It involves a target, a remote geographical location of some sort at which you station a person we call the agent. Somewhere else, you have a person we call the percipient attempting to acquire information about that target, to perceive any features of the target by anomalous means. We do carry as primary parameters in this experiment distance between the target and percipient, and the separation in time of the attempt to perceive the target and the visitation of the target by the agent. When the experiment is done, the agent at the target records data and impressions about the scene. The percipient at the time the perception is attempted dictates or writes down a free response transcript. Subsequent to that, both the agent and the percipient will fill out a binary choice sheet that permits us to do some analytical scoring of the degree of information that has been acquired about this target. This involves 30 descriptor bits, such questions as whether the scene is outdoors or indoors, whether there are trees or not, whether people are present, whether it is noisy or quiet, whether it is open or confined, and so on. The agent at the target checks off those features of the target, and the percipient does the same thing after forming a free response transcript. This provides us with the raw material for some reasonably elaborate analytical algorithms. From that comes a scoring method, some quantitative indication of the degree of information acquisition.

I would love to show you the color photographs of the many targets we have in our data base and read you the perceptions. We have this information with us, and if any of you are interested, perhaps we can hold a rump session later and do that, but it does take a good bit of time and won't fit into this talk. Let me just show you a couple of examples so that you can see the sort of thing that we are dealing with. This particular target was a railroad station in Glencoe, Illinois. The percipient in this case did identify it as a train station, identified a train when one came through, gave us some details about the inside of the station that were quite reasonable, did not

quite get the name of the station correct, but came close, and had relatively few errors in the other impressions that were dictated.

This is a target some of you may recognize, the Urquardt Castle on Loch Ness in Scotland. The percipient in this case was in New York City and dictated the transcript. She did identify that it was a ruins of a castle and it was by a body of water, it had a great deal of antiquity associated with it. There were errors; she identified a lighthouse that is not present, she spoke of a dog that did happen to be wandering around the scene. The transcript does involve a lot of provocatively accurate detail, sandwiched in with some irrelevant material.

This is a target in Moscow. In this case, the percipient spent a lot of time speaking about these peculiar stone abutments out front, did get the general ambiance quite accurate, and spoke accurately of the change in shapes over the windows and over the door.

This is one of our more famous examples. It is a circular restaurant on top of poles near the Danube River in Bratislava, Czechoslovakia. Again, in this case, the percipient identified the water, the boat, the circular shape on its side, the poles, the walkway along the top of the bridge; virtually a photographic transcript. The percipient in this case was in Wisconsin, some 5,600 miles away.

I don't have time to describe our scoring method in any detail. I've written about it quite a bit, and we have some reports here for any of you who would like to look at them.

Question (Zweig): Are these people in a trance or any kind of altered state?

Jahn: No, they are just common folks, like you and me.

Question (Zweig): Do they draw their perceptions?

Jahn: They can make sketches if they want. Some of them do. The castle that you just saw, the percipient actually did sketch out a castle abutment when she was doing that.

What we have here is a schematic representation of the data we do achieve. It is possible to define an empirical chance distribution by purposely mismatching our perceptions against incorrect targets, and forcibly scoring wrong targets against wrong perceptions. From that, you can define what you might get if you just guessed these 30 details of the scene. That, fortunately, turns out to give you a very nice looking Gaussian distribution of scores by whatever method you happen to use, and we use eight or ten different methods. If you repeat, and do the matched targets, the correct target against its perception, you see there is a definite lobe of high scores appearing out here on this side, which we believe represents the extra chance information that is being acquired. If you forcibly extract from that the largest subset of the empirical chance distribution, you are left with a residue of scores out here on this end that are somehow telling you about information that has been acquired by beyond chance means.

As I said, we are interested in the spatial and temporal dependence of this information acquisition. We performed the experiment with distances of a room or two away from the laboratory up to global distances. In this graph we are plotting scores by a particular method as a function of that separation distance. As you can see, there is practically no statistical dependence on those separation. Up to distances half way around the world, the scores do not seem to benefit from having the percipient close to the scene. Certainly no $1/r^2$ DK if one were dealing with wave propagation phenomena.

We are equally interested in the importance of the temporal displacement. We do this experiment with the percipients writing their perceptions many hours before the target is visited, hours after the target is visited, in real time, or whatnot. In all of the examples I showed you, the perception was actually dictated hours before the target was visited by the agent, in fact in some cases before the target was even selected by the random process. Again, you see how these scores array. 0 would mean the perception was dictated in real time; everything to the right was a precognitive perception, everything

to the left, a retrocognitive perception effort. Once again, there is very little dependence on time. We have taken this experiment out to several days now, and can find no benefit to doing it in real time or indeed even close to real time. The issue seems to be more one of addressing a percipients consciousness to a particular point in space or time.

In the summary of this class of experimentation, covering some 400 trials, our overall yield by these scoring methods is very high, embarrassingly high. Parts are 10^{12} to 10^{19}, depending on what scoring method you use. There is a broad range of fidelity found in these perceptions, ranging from virtually photographic ones such as I've shown you, on down through varying degrees of correspondence, to ones that are obvious misses. The significance of the information acquisition is a compounding of these increments of information beyond chance over the whole data base, rather than any reliance on just a few particularly good perceptions.

Question (Baker): Could you talk a little more about the agents and the percipients and whether or not they know each other; I'm unsure of the methodology.

Jahn: I'm sorry to be so cryptic about it; it's hard to know what details to develop in this time base. The agent and the percipient may indeed know each other well, they may be casual acquaintances, or they may be total strangers. Normally, they know one another. The percipient is addressed to the task of perceiving aspects of the target where the agent will be at a particular time. In other words, if you were my percipient, I would tell you "Jim, tomorrow morning at three o'clock I'm going to be somewhere. Please perceive it." That is the protocol of the experiment. There is a volitional variety where I would have the freedom to select that target as I wandered around, or there is an instructed version of it where I would take a target from a sealed file of a large pool of targets that give instructions like "go three miles down the road, turn left, and look at the big tree." We find no difference in the yield, whether the agent is instructed where to go or whether he selects it.

Question (Miller): Are the experiments double blind? Are the experimenters who are recording or extracting or scoring information aware of what the scene would be, or in your previous series, which direction the person is trying to influence the distribution?

Jahn: By your definition, it is double blind. The target pool for the instructed variety are prepared by a person who is not the percipient, not the agent, and not going to be scoring. The person doing the scoring has no idea of what the actual scene was. Until we actually grind it through the computer, it is done on the basis of digits, zeros and ones. Now, we can, and did early on, carry in parallel an impressionistic judging where you as third party would look at Jim's perception of my scene and decide if it was a good match, and compare it with five others and rank it. We gave that up for a number of reasons. It's now done on an analytical basis.

Question (Finkelstein): Just out of curiosity, to determine if there is any influence on the design of the experiment by some other artifacts, has anybody tried to have a computer program generate a scene based on your measuring process?

Jahn: We did generate artificial targets, a random collection of 30 bits and score it up this way, and it came out at chance.

The sort of data I've shown you force us to a position that no simple transposition of existing physical mechanisms is going to accommodate the sort of data we have collected. We are simply not going to be able to take electromagnetic theory and force it through ELF or whatever to explain the sorts of things we are seeing. There have been a lot of attempts to do this; the literature abounds with those attempts. It's an interesting set of attempts. Our persuasion is that you have to turn to a more fundamental position if you are going to accommodate the sorts of things we are finding. We suggest that one ought to step back and reconsider some of the basic premises about the nature of reality, and then return to modeling on the basis of more restrictive premises of this sort.

Very briefly, the premises we invoke are the ones you see here. Reality or experience can only be constituted in the interaction of a consciousness with its environment. It makes no sense epistomologically to speak of the environment in the abstract or to speak of the consciousness in the abstract. Only at the interaction is something generated that is experiential. The currency of that experience we call information, and that information can flow in either direction. Consciousness can receive information from its environment, or it can insert information into its environment. If we can identify the mechanisms for that information flow, we happily say that it is a normal process. If we cannot identify the mechanisms, then we regard it as anomalous and, indeed, the two classes of experiments I have shown you are prototypical of an information flow from the environment to the consciousness with the PRP work, or in the other case, from the consciousness to the environment in the random event generator work.

It follows from this that if you can only model reality in this interaction, that the concepts that you invoke to model that reality must be telling you at least as much about your consciousness as they are telling you about the environment you are attempting to model. That is to say that they are somehow archetypal mechanics that you invoke to describe the experience of this interaction. The final premise that is a little disconnected from these is that one has to replace the idea of a "particulate" consciousness with a more general wave-like perception. There have been two or three times in the history of science where it has come up again stark anomalies in its empirical experience where it has had to do this. First of all to explain the wave effects associated with light when we moved from the particulate or corpuscular model of Newton to the wave mechanics of Jung and Hoigens to explain interference phenomena, defraction, and what not. Once again, with the advent of modern physics, where it was necessary to move particulate atomic models of Thompson and others into the wave-mechanical models of Heizenberg and so on. The premise here is that one must also regard consciousness as capable of displaying wave-like properties, as well as particulate properties.

From that, one then can invoke much of the formalism of quantum mechanics itself in a metaphorical way. We actually adopt the Schrodinger Formalism and

go to the extreme of building consciousness "atoms," that is to say energy level eigenvalues, eigenfunctions of conscious experience which are discrete like their quantum mechanical colleagues, conscious "molecules," resonant structures of consciousness, the bonding of two consciousnesses or of a consciousness with its environment. Various anomalous information processes then fall out very nicely - quantum mechanical tunneling, for example; barrier penetration; information at a distance. The quantum mechanical principles that you all recognize here turn out to have very useful metaphors in the consciousness domain which we can describe in any detail you like. For collective problems, its useful to have quantum statistics at your disposal, because these are anomalous statistics that are invoked in the atomic scale and can also be invoked in the interplay of the crowd or swarm behavior situations, if you like, and a number of other anomalous effects.

Those are the three components of what we have been up to. What are the implications of this, if you want to speculate? Again, very briefly, there are some short term implications. The sorts of anomalies, the sorts of departures from classical statistical behavior that we are observing in the REG experiments, indeed in all of that genre of operator/device interactions that we described in the first part of the program, are all quite prototypical of the sorts of things one might find in modern man/machine interactions. That is to say, the chip, the VLSI, the modern micro-processor quite frequently have elements that are switching at signal levels at least as low as those at which we are seeing effects in our laboratory. One can at least raise the question of whether data processing systems, micro-processor controlled systems are properly presumed invulnerable to this sort of interaction. We have interest in the program from people who worry about the vulnerability of the cockpit controls in modern high performance aircraft. There is a possibility that in a period of stress - combat or other emergency situation -- one can assume that they function nominally, given the state of the cockpit crew consciousness under those circumstances.

The remote perception strategies have been widely deployed in the areas listed here. There are people in this room who can speak more effectively about that than I can, but we are well aware of applications in intelligence, and law enforcement, and prospecting for natural resources.

What about the longer-term implications. You might be interested in a report that is on file from the House Committee on Science and Technology back in June 1981 which contained a section on this sort of business and concluded with the remark that " . . . A general recognition of the degree of interconnectedness of mind with other minds (and with matter) could have far-reaching social and political implications for this nation and the world." I think that is right on. These longer term implications go off in many different azimuths. One can talk about the horizons of high technology and what the implications of what we have seen here might be in the long run. One can talk about personal creative processes, about extraordinary human capabilities in general. Here, I would think there would be an interest in the military in that topic. One can wax eloquent about social value systems or educational strategies. Since the thrust of at least the early correspondence on this meeting seemed to concern the educational domain, I just attempted to embellish that last category very superficially. Despite 40 years in the academic environment, I certainly don't regard myself as anything in the way of an educational specialist. However, I think it is reasonable to observe that the present-day educational structure from the nursery school on up to post-graduate level really focuses quite keenly on some linear and deductive recipes. We tend to regard experiences as causal and deterministic, we favor the analytical and quantitative methodologies, and we wax very quickly into reductionistic modeling of things which, in turn, leads to a specialization, perhaps even a hyper-specialization of talents. Certainly, we continue to take Newtonian or particulate view of things and regard the observer as dispassionately objective about his environment.

Some folks in society regard this as less than fulfilling personally and go off into some informal initiatives of the sort I've listed here, and the thesis here is that in the future, one might imagine a curriculum that combines the best of both of those sides of our consciousness. That is to say, we certainly should retain the best aspects of the contemporary educational strategies, as has been observed, which are going to be greatly amplified by computer strategies. But the contention is that this should, perhaps all the more so, be balanced by an expansion of the philosophical perspectives that underlie all of this and we've listed what those things might be.

Let me quit at that point, again with the offer for those of you who have any enduring interest in the topic that we would be glad to speak to you in more detail or, best of all, invite you to come visit the laboratory and try the experiments yourself.

Question (Perez): Are these particular kinds of events trainable; can you get better at it?

Jahn: I'm sure Brenda would like to talk to you in great detail about the process of learning in this business. A short form is that it is certainly not a traditional learning. It seems to involve more giving permission to ones self to engage in this business, and a reduction in the natural barriers to the process, and is very much a personalized procedure. We have not attempted any formal training, but people do get better once they acquire some confidence and learn to sort out productive from the unproductive strategies. In some respects, the experiments with the physical devices is a lot like bio-feedback that provides for the patient some indication of how he is doing in reducing his blood pressure or whatever. You don't really explain how; you run your own repertoire of strategies and when you succeed, you'll see the following. It's pretty much that model.

Baker: We'll break now for coffee, and those of you with more questions can catch Dr. Jahn at that time.

Baker: Our next speaker is Connie Zweig, speaking for Marilyn Ferguson and, of course, for herself. Connie is the principal writer for Brain/Mind Bulletin and Leading Edge, she has also written for Omni Magazine, and was a columnist for Esquire Magazine last year, writing on emerging technologies. Connie will speak to us now on Training the Instrument: Back to the Real Basics in 2010.

Zweig: I'm going to take a slightly different approach, because I'm not a specialist in any particular field, and what I have been doing for the last few years is tracking and monitoring different findings in the sciences, most

specifically in neuroscience, but also in other sciences. I have been trying, via the vehicle of Brain/Mind Bulletin, to get a sense of the relevance of these findings and what they might mean for fields like learning, which we are attempting to look at today.

In our work of looking at all this different research, we ask very general questions like how do we learn, how do we store and retrieve information, and how do we heal ourselves as human beings, how do we fight, how do we work, how do we break patterns, how do we create new habits. I want to suggest that a lot of the new brain models that are coming out from research these days might have some preliminary answers to some of these questions. I made a little list of some of the qualities that come to mind that I think we might train for in the future, given what we know about the human brain.

It seems to me that, of all the crazy things, educators have not been looking at how the brain learns. Nobody is really studying the learner very much. Somebody earlier today mentioned the meeting a couple of weeks ago of the American Association for the Advancement of Science. When I was there one day in my usual gathering information mode, the President of the AAAS, David Hamburg, made a statement where he said that neuroscience has been regarded in the past with extreme caution by most other scientists. But in the past decade, something very different has happened; there has almost been a migration of young scientists and established scientists into this field, and that can be seen in all kinds of ways - in the publishing of new journals, in the increasing memberships in academic societies, in new lab programs and research programs that are beginning to focus on brain research. In terms of educators, themselves, I think they have been the latest in coming around to looking at this research, and that is an irony because it is probably most relevant for that field.

When Marilyn prepared this paper you all received, she went back through the last two years of Brain/Mind Bulletin and highlighted some of the research that was pertinent to learning and training and individual development. I am going to look at just a handful of those highlights for the next few minutes, and begin by saying that we are defining the real basics here as a return to inward education, to looking at the brain/mind itself and seeing how the brain

learns, and trying to adapt learning methodologies from there, rather than going from the outside in.

I read an interesting statistic recently. A neuroscientist from San Diego said that with a single fertilization, there are 11 1/3 trillion possibilities born. The human brain grows almost like a cancer; it grows elaborately and enormously in its first few days and months, and it actually doubles in size in the first six months and doubles again by the age of four. The human brain a voracious consumer of information; it takes in information all of the time, non stop. We are now learning a lot about non-conscious learning, that the brain is processing information even during sleeping and dreaming and when we think that it is off-line, it isn't. The brain organizes itself to receive sensory information and it searches out meaning and congruence, it seeks patterns in a very natural kind of way. It doesn't have to be trained to do this.

It also seems that successful learning engages the motor senses of the brain. Successful learning uses the psychophysiology in an integrated manner. Learners who adopt skills with ease are people who are really comfortable in the learning environment, very different from how we think of the classroom. From these basic principles, it seems that the art of the trainer or educator is to generate a learning context. Someone made an interesting statement the other day -- that there is real power in controlling the context. I think that controlling the learning context is even more powerful still.

In terms of the Army training its men and women and schools as well, if you begin to think of them as brain trainers and what they are training for are brain states, not tasks, I think it would be useful. Learning could be seen as a state of consciousness, maybe even an altered state, and mastery could come to be seen as not mastery of skills, but mastery of the learning process. Some of you may have read in some of the popular science magazines recently that there was some initial evidence that came out, probably the first evidence at this level of brain function, of creativity or enhanced learning in Albert Einstein. A woman at UC Berkeley named Marian Diamond, a neuroscientist, got some bits of Einstein's brain which had been stored over

all these years, and was able to analyze them. She found that in fact in specific regions of the brain that appear to be associated with the kinds of mental activity he did, there were more glio cells per neuron in his brain than in normal people, and it was compared with the brains of 11 other men. The glio cells are considered to be the support cells for the neurons; they have conventionally been thought to not be active at all but to nourish. Perhaps -- because this is very preliminary -- this is the first physiological evidence of change at the cellular level in the brain from highly creative, symbolic thinking.

Another field of research that fascinates me is the disorder called the multiple personality. I think that multiple personalities, although in psychiatry they are thought to be pathologic, have some implications for people who are looking at learning. There are about 5,000 people on record now with multiple personalities; these people dissociate at a very young age from extensive child abuse. It tends to be before the age of five. They have a very abusive situation with one of their parents, and in order to function in that environment, their brains learn to dissociate -- they go away -- and create whole other ego states or personalities to contend with the pain or to do other unwanted tasks. It seems that when they become adults, some of them have up to 100 or so independent personalities. These personalities actually learn different skills. The recent physiological research that has been done on them demonstrates that they are not sub-personalities, like some of us get confused sometimes and say that one part of me wants to go that way and another wants to go this way. The multiples actually have different electrophysiologies, different brain states for different personalities. They have different allergies; one personality may be diabetic while the others are not; one personality might be allergic to citrus fruit and another one may not. Some of their personalities develop so autonomously that they have different ages and different sexes than the original, dominant personality -- the executive personality, they call it. There are concrete parameters coming out now to measure this seemingly bizarre phenomenon.

The reason I wanted to bring it up is that I think it demonstrates very clearly the plasticity of the human brain, the range of possible learning that we have, that we really don't take into account. When I was writing about

this, I spoke with a woman who was clinically diagnosed as having 180 different personalities. She speaks as a "we." I might say that before therapy, multiples have complete amnesia between states. If they don't yet know that they are multiple, one personality is not aware of the others. This woman had been in therapy for a long time, and she was very aware of what was going on with her. In fact, one personality was getting a graduate degree in psychobiology. She might be working on her dissertation in one mode, and another personality would be cooking dinner, and another personality would be doing something else. She had learned to split herself off in these kinds of very functional ways. We tend to think of splitting off as pretty abnormal condition, but she had adapted to the situation such that one personality had learned a number of foreign languages that none of the others knew. She also had a healer personality. There is some evidence that a lot of multiples are able to heal themselves more quickly that other people.

This is very strange stuff. This is not accounted for in the way we understand the unity of personality, the unity of the body and mind of a single individual. I want to throw out a preposterous suggestion that there may be a way to creatively use dissociations to learn new skills. We could think of it as a creative tool, a training tool, rather than as a pathology.

I also wanted to mention a theory that came out a few years ago by two researchers named William Gray and Paul LeVilette who were doing some work on the relationship between thought and feeling -- they called it emotional cognitive structures or feeling tones. As all of you know because you have all been through the school systems, it is fairly rare that educators and trainers take feelings into account. I don't just mean emotional feelings; I mean the felt sense that we get of things very instinctually. What these two men are saying is that the feeling tones underlying our basic cognitive experience, our basic basic thinking patterns, are the context, the organizing principle for thinking. The example that I recall was that when most people are growing up, they have one or two general feelings about themselves in relation to others. One feeling is that they are locked in -- into a group or into a family or a classroom or a country. As adult, they appear to develop a breaking out pattern of behavior. People who, when they are very small, feel locked out tend to develop break in behaviors. There are many feeling tone

patterns like this that help to develop personalities and later behaviors and later learning styles. I think that we need to take more into account the underlying feeling of our learning environment and what kind of effect it is having on the learner. I would say that a positive learning environment is no longer a luxury; it is the basis for efficiency in learning.

I just mentioned a couple of minutes ago that there is some research being done now on non-conscious or unconscious learning. I would like to describe a couple of these things, because we also tend to drop these out of our definition of education and training. There was a study done where it was shown that when babies learn something new and then were given an interlude of sleep, they could recall the new information more easily. Sleep somehow allowed them to integrate the information and to activate their retrieval process. Often in the learning environment, it is not taken into account that the brain needs to stop processing to integrate information. Sleep is actually an active information processing mode. On a personal note, I write an intense amount of information from one week to the next. The only way I have found to do that is that I will gather a lot of data, and then I will sleep on it. When I wake up in the morning, it is almost there is perfect form; it comes out in huge chunks, ready to be written. If I remain in the mode of taking in concepts and ideas, my brain is somehow not ready to change gears.

There is also a study that is not new, but I believe it is pertinent to the military context for learning, and that is the relationship between social interaction and dominant behavior and neural chemistry. Michael McGuire at UCLA studied monkeys. What he has found is that the dominant male monkeys in a group have higher levels of neural transmitters called seratonin. When a dominant male monkey is removed, within 48 hours there is a new dominant male in charge. Within seven to ten days, that male monkey has a peak of seratonin, just like the former one. That's easy to write off, perhaps, except that this same tendency was found in human beings. When they looked at law students in a university, they found a similar phenomenon in low and high status university students. There was a neurochemical difference that they could track based on how the students felt they were interacting with their

peers. For me, that brought to mind the ranking system of the American military and what that might have to do with learning ability.

There is another study that is also written off as silly, and yet I think there might be something here. The researchers were able to create a sense of social unity in a group through subliminal messages. There were two experimental groups, one that heard the subliminal message of "Mommy and I are one," and another group that heard "The professor and I are one." In both of those groups, student grades went up. In the control group that heard a nonsense message or neutral message, there was no change in their grades. Extrapolating, speculating from there, I think we might be able to say that trust is a trainable brain state that has some very intimate connections to learning.

In conclusion, what seem to some people to be hard, cold facts of science reveal some remarkably extraordinary human abilities that have a lot to teach us about how we can, in effect, redesign our learning environment and our own brain. The newest way of thinking about the brain is that is a very dynamic, self organizing very complex bit of matter, and it deserves the role that it is beginning to get at the front and center of the sciences. The brain is built to be challenged; it works optimally when its processing requirements are at the max, when the whole brain is being called upon to function. I think that its biggest challenge in the future is in understanding itself.

Baker: I'd like to make one observation about one thing Connie was talking about, which is taking breaks and being able to absorb. I think that the military had the lead on this in the classic psychological theory called distributive versus mass learning. It was found originally to enhance learning of Morse code, as I recall. It was found that the shorter the training session and the more breaks in between, the greater the learning. That has a very solid foundation in psychology. Why you don't forget when you sleep is the interference theory of forgetting that says you don't have an opportunity to have other things interfere. The point I am trying to make is that there is just a lot of basic psychological theory that people observe and

discover after the fact that has been worked on and has been applied in other settings.

Question (Hart): I understand your role as a synthesizer or gatherer of information. Have you been able to put together any kind of projections for the future as to time lines for topics of research across the region or the world, where they think certain kinds of discoveries will occur. Have you been able to chart that kind of evolution?

Zweig: It is so much just keeping up with what is happening now that I would have to say no, not really. Scientists don't appear to make scientific projections in that kind of way very much.

Baker: We're now going to address the question of government research and development efforts related to training technology. To do this for us will be Dr. Henry Halff who is the chief scientists for Halff Resources, Inc. His major areas are cognition, computers in training and education, and artificial intelligence. Although he didn't put it here on the card, I'll mention that I was pleased to see Henry; I hadn't seen him for awhile. When he was with ONR, there was a group of us who formed a group called the Washington Executives for Instructional R&D. The only reason we formed it was that we loved the acronym WEIRD.

Halff: I guess I am as weird as anybody in that group. Let me tell you about how I got to be standing up here in front of you. In the middle of March, Ray Perez called me up and told me he had a job I might be interested in, and to come on over. I went over, and he explained that what he wanted was somebody who was interested in this planning effort that we are engaged in now, which covered several emerging technologies and their impact on Army training over the next 25 years. He wanted me to go out and find out what the other government agencies had planned in this regard. He said he wanted me to focus on biotechnology and telecommunications, but if I found anything else out there, he wanted a full report on that, too. I said it sounded like an interesting job, and asked him when he would like it done. He told me that he

wanted it by April 8th. That was in three weeks. I scratched my head and decided that it was either a three-year job or a three-week job, and it would probably be a lot more fun if I did it in three weeks. I spent two weeks calling everybody I could possibly think of in the government and all the people they thought of for me to call, and then spent one week writing.

Before I tell you about what I wrote, I better introduce the authors of this particular report -- all the people I talked to. If what I have to say to you is good, it is because of the contributions of these people I called and visited. If it's bad, it's probably because there were just so many of them, and you can't have that many people involved in one report.

I want to talk about four different areas. Two of them were similar to the ones Ray told me to talk about. He assigned biotechnology to me, and I tried to learn real quick about that. I knew nothing about it in the middle of March. He also told me to talk about telecommunications, but I found that it was impossible to separate out the impact of telecommunications on training in any realistic way without talking about other electronic technology like videodisc, so I expanded that part. I wanted to cover neural sciences and cognitive sciences simply because they seemed to be of particular interest to the government at this point in time.

As I say, I have learned about biotechnology rather quickly, so my view is rather superficial. The people who really gave me my education were Bob Raven at NSF who runs a program to coordinate federal research in biotechnology, and a woman named Gretchen Kolsrud at OTA has put together a marvelous report on the subject that I recommend to you all. Biotechnology seems to me to be two things. One is recombinant DNA techniques where you can make new kinds of critters, and these new critters can make new things for you. The other aspect is monoclonal antibodies. An antibody is a substance that will react inside your body to a particular antogen or host, and consequently they are useful these days for research, primarily. In the future, you can expect to see some practical uses. One of the things Bob realized quickly was that this technology almost immediately makes possible new and incredibly terrifying forms of biological warfare. You can make just about any vector for just about any toxin, as long as you do the right gene-splicing experiment. A

force that is under attack by one of these biological monsters would be in very bad shape. The situation is compounded because these are weapons that don't go away once you have used them. As a matter of fact, they grow. I have no idea what sort of training, or even if people could be trained, to protect themselves against biological warfare, but for sure it is something that the Army of 2010 should worry a little bit about.

One of the things that I found lacking in research on molecular genetics was a consideration of the computational aspects of molecular genetics. Just to give you an example, it seems like antibody and antogen systems are, in fact, wonderful systems for pattern analysis, pattern matching, and pattern learning, but they haven't been analyzed on that level. The molecular genetics community, at this point, is primarily concerned with the manufacture of biotechnological products, rather than with an abstract characterization of the computational processes involved. Perhaps they are kind of at the level that single-cell people were maybe 20 years ago, and don't realize that there are systems issues involved.

Further down the pike, as we've heard, we can foresee progress in the area of computational biotechnology, that is the manufacture of logical devices based on molecular biological processes. In my scouring of federal agencies, I found a certain amount of interest in this, but not as much as you might expect. I found absolutely no interest in using computational biotechnology in the interest of training. Finally, there have been suggestions that biotechnological products could be used as neural prostheses in a number of different ways. Perhaps the most prosaic way would be that they can manufacture pharmaceutical agents that would improve people's memory abilities. At the other extreme, you might think of kind of by-passing the sensory system and, if you want somebody to learn something, you just plug the knowledge physically right into their brain. In between, there are other alternatives, such as if you want to give somebody a little bit more of a certain neurotransmitter, you implant in their brains a bug that manufactures it. I guess you might call those man-made glio cells.

Where is the government going in the area of biotechnology? Their primary interests are in agriculture, manufacturing drought-resistant plants, that

sort of thing; in medicine, pharmaceutical applications, diagnostic instruments, the basis of monoclonal antibodies; in industry, the manufacture of new kinds of materials, coatings, for example, and new kinds of paints. As Dr. McAlear has mentioned, there is a certain amount of interest in biological computation, but the programs are small and I think somewhat tentative. At least among the people I talked to, there was no clear vision of where the hardware based on these kinds of principles was going. Everybody I talked to in the areas of biological applications said that they had absolutely no thoughts regarding application to training.

This wasn't the case in neural sciences. There is a lot of interest in these sciences among government agencies, and there is a strong feeling that a better characterization of the neural system is somehow going to lead us to more effectively trained people. I can try to characterize that interest in terms of four scientific levels. There is an interest in neuroanatomy -- the discovery of increasingly complex functions within particular neurons, neurons carry more than one neural transmitter, for example. At another level, there is strong interest in the study of the synapse, and particularly how the synapse changes with stimulation, with the obvious feeling that if you know how a synapse changes, it will somehow tell you something about learning. Third, there is a certain amount of interest in how the nervous system works as a system, how computation takes place. There is an interest in addressing the kinds of issues that Dr. Miller talked about. How can you characterize attention, as an example, as a characteristic of a nervous system? Finally, at the highest level of abstraction, there is this general interest in how you can do parallel computation and process information in something like the nervous system -- purely for computational purposes, with no attempt to actually model the human nervous system.

Where those things are going as far as training is concerned includes neurochemistry and pharmacology, thinking about learning disabilities and biochemical deficits and pharmaceutical agents that might be necessary or reasonable to counter those kinds of disabilities. There is a certain amount of research that is being carried on along those lines. We might also think about developmental issues. I guess it is well known that the nervous system changes with development. Parts of your nervous system are plastic at one age

and not plastic at another. When the services get people who are ready to be trained, they are unfortunately in the position of having to train or educate people at an age far beyond the time when people are normally educated. They get recruits who can't read and have to teach them the kinds of things that they should have learned when they were five or six years old. It might be interesting to think about pharmacological applications that would return somebody to an earlier biochemical age, and thus increase their learning ability.

At the other end of the spectrum, neural models of computation offer a lot of power simply for pure computational uses. We can make better use of computers if we can incorporate some of the powerful methods used by the nervous system. In particular, we should be better able to model human information processing and thus obtain better control over training methods. The more precise you can get over exactly what information processing is going on inside an individual when he is being trained, the better control you will have over the training environment. In general, parallel computation should improve training technology, and in particular, simulators. Not only are our brains parallel, but the world is parallel. There are a lot of things going on at the same time. If you are building a simulator of the world, it makes sense to use parallel computation as the basis of that simulation.

Like I said, there is a lot of government interest in neural and neural-like information processing. DARPA has a couple of demonstration projects in highly parallel computation. The Air Force is looking at the physiological bases of attention in a program that they call "bioreactivity." They have also been looking for some years at learning in neural-like networks. The Office of Naval Research has a three-year-old program that looks at the neural bases for learning and memory, and at least vague intentions of starting a longer-term project to look at biological models of intelligence. The National Science Foundation has five programs that either directly or indirectly address the kinds of issues I've been talking about, and NIMH also has an obvious interest in this kind of thing.

Up to now, I haven't talked about anything that anyone in the Army or any place else has to do. I think it is an interesting characteristic of the

kinds of things we have been talking about today in this context that nobody has talked about actual, real training needs, either now or 2010. When they talk about these kind of global technologies for training, there is no mention, for example of how improvements in nutrition would impact on training for a particular skill. The science of biochemistry and neuropharmacology simply doesn't address things at that level. To get to the level of particular skills, of particular things that people have to learn how to do, you have to pass to cognitive science because that is essentially what cognition is all about.

For five or ten years now, there has been strong interest in cognition in the government. I think it will continue to be strong in the immediate future. There have been some things we have learned over these past five or ten years that should help us improve training. One is that you have to be precise about what you want people to do with their brains or their minds. It is very important to achieve a cognitive model of what you are training people to do. It's important to be explicit at the level of cognition, because all the hardware in the world won't give you the kind of power over human action and human thought that you need with this kind of explicit model. It's important to keep in mind that hardware isn't smart. No matter how many devices you can put in a square centimeter or how fast the switches are, the hardware isn't smart -- you have to know what to put into it. The other thing that I think we've learned is, at least at the cognitive level, there is no magic. There is nothing you are going to do at least by way of training through what we consider traditional training methods to increase people's general intelligence. If you want somebody to learn how to do something, you are going to have to teach them how to do it. You can't teach them something else. You can't teach a person one thing and then, all of a sudden, have them know how to do a whole bunch of other things. We see it in experiment after experiment and domain after domain. If you want somebody to learn a particular skill, teach them that skill.

The technological edge in cognition, as Dr. Miller mentioned, is with automated tutors and perhaps with intelligent job aids. The distinction is blurring these days, so I won't make it, but it is important to keep in mind that these kinds of technologies are limited. One of the fundamentals of

cognitive science is that it is based on a symbolic representation of the world. Consequently, any hard application of cognitive science has to deal with an attractable, symbolic representation of whatever you are trying to teach. In many cases, it is simply impossible to achieve such an attractable, symbolic representation. If you are trying to teach somebody how to repair a radio set, it's reasonably easy to represent that set and the problems with it in a machine. On the other hand, if you are trying to teach somebody how to deal with global economic crises or strategic problems, it is simply impossible to encode that information in the machine, at least within the time frame in which it's useful. You might be able to get it in, but by the time you got it in, it would be different. So it's important to realize that automated tutors, although they offer a lot of power, are limited in their scope. They can help us in certain areas, but will be of no help in other important areas.

Who is working in cognitive science? Again, as I said, there is a lot of interest. ARI has a strong program; NIE used to. but they have been subject to such turbulence recently that it is very hard to speak of them as a strong force in the area. NSF has a strong interest in basic research and also a new slug of money that is being pumped into basic studies of science and mathematics education. The Office of Naval Research is probably the one agency that has been responsible for developing cognitive psychology of real world skills. They also have a strong program on automated tutoring.

The last area I want to take up is electronic technology for training. A typical way of breaking this down is to take the separate technologies. There is telecommunications, and then there is video, and then computers. You might separate out man/machine interfaces and all that, but it doesn't make sense from the standpoint of training to talk about it that way. If you want to talk about training technology, the best way is to start with training. Training in the military is done to a certain extent with traditional classrooms, but that is not where the interesting action is. The unique and interesting aspect of military training is that it is done a lot with simulators. I think the military got interested in this originally because simulators were cheaper than the real thing. They are cheaper, and less hazardous, and have all sorts of interesting characteristics.

The interesting thing about simulators these days is that they are not like the real thing, and I think we are going to see a period over the next 10 or 15 years in which we begin to take advantage of the fact that simulators don't have to be like the real thing. I have pointed out three ways that you can take advantage of this fact. One is that you can use a purposely non-faithful simulator to give a psychologically more faithful training experience. I'll give you a couple of examples, one teeny and one large. The teeny one is that Jack Thorpe at DARPA is putting together a simulator for tanks. He wanted to put the noise in the tank that would people feel like they were in a real tank. The obvious thing to do was to record the noise from a tank, but Jack went to see someone in Hollywood and asked how he would do it. The guy took a recording of the noise from a tank and he enhanced it so that now it is nothing like the noise from a tank, physically, but it sure sounds a lot more like the noise from a tank than the recording. Again, it's an attempt to give people the psychological experience of the noise.

Another example, far more wide ranging, I found in the educational technology division of the Education Department. They put together a large packet for science education that consists of video tapes, an Apple computer with appropriate programs, and a lot of printed material. Using these things, kids in science classes can take a voyage around the world. It's called The Voyage of the Mimi, a little ship, and it is extended over a semester. None of these technologies is very faithful at all. If the Navy built that simulator, they would have a bucket of saltwater that they would slosh over the kids every once in awhile. In any case, the kids in the classroom have a much more faithful psychological experience of what science is really like and how to do scientific investigation than they would if they tried to make a faithful simulation of this kind of experience.

Finally, the worst simulator of all is no simulator. I think the Army should realize that, as a matter of fact, because some of the simulated exercises for you guys are so expensive that you simply can't do them, you can't send everyone off to the National Training Center every few months like you should. I found that out from the GAO. At a certain point, you should be willing to trade fidelity for cost savings. If you can put a cheaper simulator out there that everybody can use, do so.

Another aspect of technology and training has to do with its social nature. Maybe it's more the social nature of war. War is, in effect, a social enterprise. It involves collections of people fighting other collections of people and you can't ignore that in training. When it comes to the use of technology, it can in fact improve the use of human resources in this respect. I'll never forget going down to the Naval Training Center in Memphis where they train air traffic controllers. What you see is one guy learning how to be an air traffic controller, and four guys pretending to be airplanes that he is learning to control. To do this, you have to find four other guys, in the first place, and you're wasting their time. It's clearly an advantage to have a machine do the four other people, and you can press that advantage to an even greater extent, involving large numbers of machines, large numbers of people, and nationwide simulators. Of course, that's the dream -- to have everybody hooked up in a grand air war simulation. It does more for you, even if it is not very faithful, than improve the use of human resources.

You find that communities develop around these things. I don't want to say the training community, because that is the community of people who do the training. What I want to talk about is the community of people being trained. Even today, you can see it. There is a nationwide time-sharing service that offers war games, science fiction war games. All of a sudden, you see among the people who play these things, a community building up. If they went to bars after they play these games, they wouldn't talk about girls or whatever, they talk about the games. That could be of tremendous importance to the military. It could be very important to have somebody in Arizona who has had the same kind of experience and has the same kind of knowledge as somebody in Boston, who has been training with the same system. For one thing, they are kind of interchangeable. But for another, they are more cohesive as a fighting unit. If you can do it across services, it may be a way of bridging the gap, and some of the coordination problems between services.

Finally, technology obviously gives you new ways of dealing with the curriculum. It can teach new things. There is a program that you can buy for your kids that will teach a seventh grader digital logic. That just wasn't

possible a few years ago. You can also use electronic technology to help you build better courses faster.

NSF and NIE have programs going in electronic technology, but I found the most important and exciting work going on in the Department of Education and at DARPA. In addition, all of the service laboratories have interesting work going on.

Ray kept hammering me when I started doing this to know what the other agencies are planning. You want to know what people do when you call them up and tell them that you are working on a 25-year plan for training for the Army? They laugh. Universally, they laugh. There isn't any plan, and maybe there shouldn't be. Why isn't there? One reason is the principle that you can control a lot of things in the development of technology, but you cannot schedule ideas. You can't say that you are going to figure out the secret to language in 1988. Maybe you will and maybe you won't, but you sure can't count on it. The other thing is that the bigger your plan, the more time it will take to implement it, and the more uncertain you will be about things that will happen, contingencies that will affect it over a long period. That is why people normally plan from day to day or year to year. Agencies have one-year plans, usually. They may know something about five years, but it is just magic and hand waving.

The only people who do not understand that principle are the people who do military weapons system development. A ship that is commissioned today has a computer that was designed ten years ago. Would you buy a computer that was designed ten years ago? It's insane. It also means, by the way, that if you are planning for the Army in 2010, you have to do it with the technology, say, that is available in 2000, or maybe 1990, or maybe today.

Baker: I mention in passing that one of the more interesting generic simulators was one that he didn't have time to talk about, which is STEAMER. It was meant for psychological enhancement, and really doesn't emulate with a high fidelity the actual operation that it was intended to simulate.

Closing out the formal presentations will be Technological Forecasting with Confidence. I am especially interested in hearing how you do this with confidence, because I have heard futurism mentioned in the past as being one's ability to stare into a crystal ball and come out with some notions about what will happen in the future. Many times when you get profound and state some things, it means that eventually you might have to eat your own words. Those who use a crystal ball many times found themselves on a diet of ground glass. I understand that Joe Martino is going to tell us how to avoid that problem by giving our predictions with much more confidence.

Dr. Martino is a senior research scientist at the University of Dayton Research Institute. Of course, his area of research is technology forecasting. He is the associate editor of Technological Forecasting and Social Change; technological forecasting editor for The Futurist; and the author of Technological Forecasting for Decision Making.

Martino: I notice on the schedule that I have until 4:15 and it is now 4:18; time for questions. Perhaps I can do it backwards.

Well, what is technological forecasting? The definition I use is "a prediction of the future characteristics or applications of useful machines, techniques, or procedures." Several points should be noted about this definition. First, the inclusion of techniques and procedures means that technological forecasting is not limited to hardware technologies. The biological and behavioral technologies are just as much the province of the technological forecaster as are the more conventional hardware technologies. Second, the restriction to "useful" technologies reflects the view that technology is intended to serve some human function, and does not exist for its own sake. Third, the word "characteristics" in the definition is intended to mean that the technological forecaster is not required to invent what he forecasts. It is sufficient to warn that some level of performance will be available. This is particularly important when the forecaster predicts a level of performance which will require a breakthrough to be achieved. The forecaster's task is completed by the prediction of the breakthrough; inventing it is outside his responsibilities. Finally, the inclusion of

"applications" within the definition reflects the fact that a large share of the technological forecaster's efforts go into predicting the rate of adoption of some new technology, or the rate at which a new technology will replace an older technology.

Why forecast technology? The reason for forecasting it is the reason for forecasting anything else: increased control over one's circumstances. By knowing what technological changes are likely, the decision maker is in a better position to take advantage of the changes, or to minimize their adverse impacts.

The most frequent use of technological forecasting is to make decisions about the initiation or termination of technological activity. In some cases, the technology appears to be "inevitable," but there is still a question of timing. When is it going to be available? When should your company or agency get on with it? A premature start may mean that you lose considerable time and effort trying to commercialize or deploy a technology that is not ready yet. A late start means that your competitors get there first. Even with a technology that seems to be the "wave of the future," there still may be important questions about timing. An example of this problem is the laser, which through the 1960's and early 1970's was characterized as a solution looking for a problem. Many people jumped onto the laser bandwagon without first verifying that the technology was ready for application. As I recall, its first commercial application was cutting patterns for dresses.

At any rate, technological forecasts can be helpful in deciding when to get started on a technology. Similarly, they can be helpful in deciding when to get out of a technology. A forecast of a successful replacement technology has the information you need to determine when an older technology should be dropped. Here again, timing is the critical problem. To abandon an older technology too soon may mean leaving a gap which competitors can exploit. The competitors may find a way to squeeze out one more generation from the old technology while you are trying to make the new one work. This is what happened in the case of the British Comet, the first commercial jet airliner. Although it was a technological marvel, it was really premature from a

commercial standpoint, and other manufacturers managed to get the final generation of prop-driven aircraft out of the old technology.

Another example is illustrated by the decision of the Boeing Company in February of this year to delay introduction of its new generation of 7X7 aircraft. For quite some time, Boeing had been approaching a go-no go decision on introducing this aircraft in 1989. With forecasts that several new technologies would be available in 1992, Boeing decided to postpone introduction until these new technologies could be incorporated. They recognized that had they gone ahead for 1989 introduction, the airlines would have postponed purchasing; they would have known that new stuff was coming in three years. Why buy an airplane that is going to be obsolete in a hurry? With a forecast of the timing of these new technologies, Boeing was able to properly base its decision to introduce this new aircraft.

These are some of the uses of technological forecasting. What I really want to get at is how do we go about it. What is the nature of technological forecasting? A question is how is it different from forecasting anything else? The important point is that it is not. To describe forecasting, and specifically technological forecasting, I need a framework. There are probably lots of them, but one that I am going to use is based on the fact that all forecasting starts with data about the past, and applies to that data a change law believed to link the past to the future. Therefore, we can categorize forecasting methods according to the change law, or the rule, by which they link the past to the future.

There are four "pure" types of forecasting, and these four types apply to all forecasting areas, not just technological forecasting. A given forecast may use a combination of the pure types, but it is still recognizable. These are extrapolation, leading indicators, causal models, and stochastic methods.

Extrapolation methods assume that the future of some time series can be predicted by utilizing only the past of that same time series. Preparing a forecast then means extracting a pattern from the time series and projecting the pattern. Typical patterns include growth curves, trends, and cycles. Once you have decided that a particular pattern is appropriate, then the only

issue is fitting that pattern to the data, usually by some mathematical method, and projecting.

Leading indicators assume that the future of one time series can be predicted using the past of another time series. Changes in the other series, the leading indicator, are assumed to give advanced warning of changes in the series of interest. The method is popular in economics, where forecasters look for "turning points" in a leading series to forecast turning points in a lagging series.

The third method, causal models, assume that the forecaster knows the elements involved in the subject area, and the linkages among them, in the same sense that the physicist knows the elements involved in a mechanical sense and the linkages among them. Forecasting in either case is then a matter of working out the consequences of initial conditions, and taking account changes in boundary conditions. Use of causal models depends upon being able to define the "system" involved, to identify its elements and their properties, and to identify the relationships among the elements.

These three methods, extrapolation, indicators, and causal models, all assume that there is a one-to-one correspondence between past and future. A given constellation of past and present circumstances can give rise to one and only one future. Stochastic methods, on the other hand, assume that even given a specific constellation of past and present, the most one can say about the future is to give a probability distribution over a set of possible outcomes. The information contained in the past data is completely incorporated in the probability distribution, which may say that one outcome is more likely than another, but it does not narrow the range of outcomes to a single one, as do the other methods.

In practice, these methods are usually used in combination. For instance, when a trend is fitted to a set of data using regression methods, usually one computes confidence levels, as well. This represents a combination of extrapolation and stochastic methods. However, you can usually identify one method as being primary. Now that I have provided the methods and a framework for talking about technological forecasting, I want to illustrate the methods.

In extrapolation, the technological forecasters typically use less sophisticated methods than are used in other application areas. The primary reason for this is the nature of the data we must work with. Methods used in business forecasting, such as Box-Jenkins and Exponential Smoothing, are designed to take advantage of equally spaced data, data that are available weekly, monthly, annually, whatever. It is very rare that the technological forecaster has data which are equally spaced. As Dr. Halff pointed out, inventions come when they come. They don't come on schedule, and especially, they don't come in a regular order. So, the extrapolation methods we use must be robust enough to deal with unequally spaced data, which means we cannot use the sophisticated methods you find in other application areas.

Another feature of the data with which we have to work is their monotonicity. Prices may go up or down; temperature may rise or fall; but technology almost never regresses. Therefore, we are concerned with methods that do not allow regression; in particularly, the cyclical methods are of virtually no interest to the technological forecaster.

Here are some examples of extrapolation. This one has data points showing speed in miles per hours of U.S. combat aircraft from the first Wright Flyer bought by the Army Air Corps up to the F-111. Note that the data points include aircraft with wood and fabric construction, all metal, closed cockpit, yet you cannot tell from that set of data when the new technologies came in. Each breakthrough came, in fact, as it was needed to continue the trend. A word of caution here. Extrapolation does not mean we are predicting that the future will be like the past. Sometimes, people condemn extrapolation saying that is what we are doing. No, not at all. You don't see any airplanes on this graph. What you do see is a plot of a particular performance measure. The forecaster, in extending this plot, would not be saying the airplanes of the future will be like the airplanes of the past. The forecaster is saying change in the future will be like change was in the past, including the breakthroughs. If we had breakthroughs in the past, we will have them in the future. I absolve myself of the responsibility to predict exactly what they are going to be; I'm simply saying they will come along when necessary to keep the trend going because they did before. That is precisely what we mean by extrapolation: change in the future will be like change was in the past.

Question (Hart): You have some points that go below the line then go back up above the line. Are those break points?

Martino: Actually, they are not. They are depression points. The prop to jet breakthrough came in here; you can't tell it on this plot. The breakthrough in this region was fabric to metal, and actually the fabric planes look above the curve. What is going on here is between the wars, technological stagnation in military aircraft. We take it for granted that technology is developed by the military and then adopted into civilian life. From 1920 to 1940, it was the other way around. Any advance in military aircraft was preceded by an equivalent advance in civilian aircraft.

This next plot shows growth in takeoff weight of fighter aircraft. Again, it is a good fit to an exponential trend, up until it came to a halt. The F-15, the F-16 are way down here. Why? This is one of the issues I want to address. What happens to trends; why don't they continue? If we project this trend and the previous trend, speed and weight, by 1990 or so you will get a Mach 6 aircraft with a takeoff weight equal to a C-130 transport. Whether this is technologically feasible or not is open to question, but whatever it is, it doesn't look like a fighter plane. These trends were brought to a halt, not by technology, but by deliberate choice. We did not want to go that route.

This plot shows passenger miles per hour productivity of commercial transport aircraft. That's the 747 right on the trend. An interesting point is that the Concorde and the TU144 supersonic transports fell way below the trend. In retrospect, it is not hard to see why they were economic failures. They could not compete in productivity with the 747 and its comparable subsonic transports.

This next plot shows improvements in illumination technology, and it illustrates the point that I was making that breakthroughs tend to come when they are needed to preserve the trend. Or what really happens, I think, is that they are lurking in the woodwork and as economic demands occur, they come out of the woodwork. There has been some inventor hiding back there with it

already developed. When steam engine time comes, use steam engines, but before that you don't really need one.

Question (Finkelstein): The last breakthrough was 20 years after the previous one. Somebody waiting around in 1945 or 1950 for the next breakthrough will have a hell of a wait. How do you know it won't be the next century?

Martino: Your question is a good one, but let me come back to that when I get to stochastic methods, because that is one of the things we look at. What is the frequency distribution of these intervals, because we hope to be able to use that information to say something about answering this question.

We haven't seen anything new for awhile, and when you look at some of these, we are just about at the theoretical efficiency of white light. This trend is coming to a halt, because there isn't any way to do any better.

I mentioned that we are not restricted to hardware technologies. I would like to show you one software technology to illustrate the point. This plot shows dollar magnitude of engineering projects, and note that I have data running from around 1790 up through the Apollo project in the late 1960's. There are lots of projects down in here; we built lots of things that were cheaper. I was interested in the envelope, what was the biggest, so I concentrated on these events out here. That's an exponential trend -- the envelope of our ability to manage a complex project is growing exponentially. I argue that dollar cost is a measure of the complexity of a project, and we are learning how to manage bigger and more complicated projects -- not just learning now to spend more money, although that, too. In all cases, I had the actual cost. In some cases, I was able to find the initial estimate. In no case did the initial estimate exceed the actual cost. Moreover, the ratio of final cost to initial estimate ran about three for the last 200 years. We haven't learned much in curbing overruns in 200 years.

Question (Zacherl): Could the exponentiation be in the complexity, in the management of the goal?

Martino: I think it is largely in the ability to combine more and different kinds of skills and over a lot wider geographic spread. We're talking now about an integrated, coherent project that you just couldn't have done. For instance, one of these plots back here is the Panama Canal. If you look at the way the French attempted to build the Panama Canal, they split it up into sections and assigned each section to a separate construction company with no attempt to integrate the operation. When the canal was actually built successfully, it was built as an integrated whole, showing improvement in managerial capabilities over that interval. I argue that is what we are seeing -- the ability to put together in a cohesive package bigger and bigger projects. The chart is in constant dollars. The inflation is still there, but the growth rate is so much bigger that I didn't worry about it. In fact, it was tough enough converting many of them from foreign to U.S. currency.

Question (Henderson): Most of the projects you are describing seem to have a very large hardware component in them. What about a more software oriented project such as managing a national economy that no one knows how to do yet.

Martino: I'll answer that in two parts. One, I disagree that these have a hardware component. The basic cost in all of them was labor; labor costs more than anything else. You end up with something physical, but the bulk of the cost generally is labor so that is why I say that it measures managerial capabilities. As for managing an economy, you're right that nobody knows how to do it, but I'm not even sure that an objective of "to manage the economy" even makes sense. I understand that when I am building a canal, I want to have a canal when I'm done. If I say I want to manage an economy, what does that mean? There is no objective for a economy, so it is not really the same kind of thing.

Question (Hart): I am wondering if we aren't talking about a different kind of change, the old notion of "chunking." I am wondering if it isn't that we haven't learned how to manage better but we have been chunking our materials into larger dollar amounts by simply the way in which the economy has grown. I don't know that it is necessary that it follows that we have learned how to manage bigger projects better; our elements have changed.

Martino: I won't dispute the point. I will simply say that we can take a project with more people with more different kinds of skills and doing more discrete activities and manage it when it couldn't have been done before. Whether it is chunking or whatever.

Question: But when you use the ratios of overruns, it is still three to one. I think we are operating with the same mentality; we just have bigger things to chunk it into.

Martino: What probably has happened is that we have never put any emphasis on curbing overruns. We have put all our new-found ability into pushing out the frontier of the do-able.

Let me move on, because I am going to get the hook here shortly. I have shown you a number of plots, but as I mentioned at the outset, performance is not the only thing we worry about. Sometimes we are asked to forecast diffusion of a new technology. I want to show a plot that illustrates the substitution of diesel for steam locomotives. This scale shows ratio of diesel to steam tractive effort available to U.S. railroads. We have a plot here from 1935 to 1940. It falls on a nice straight line and extend it, and that would be your forecast. Let's take a look at how well you would have done if you had made that forecast. The final results show the actual history of the substitution of diesel for steam. You note that the forecast made on the basis of data from 1935 through 1940 is not bad. That's a pretty good forecast. But imagine that you are a technological forecaster back in 1940, and you have these first five or six data points. You walk into the office of the steam locomotive manufacturing company. At the time, remember that his technology has 99% of the market. You say to him that in 10 years his product is going to be on the way out, that he will have less than half the market. You would have been right, but it would have taken an awful lot of nerve to make that forecast. Making these forecasts is sometimes a nervy business.

The next method I want to show you is leading indicators. Here is one of the ways that we do this. This is an illustration of going from an experimental device, in this case an experimental aircraft, to seeing the same performance in an operational device. Knowing that there is a fairly constant

lag, one can use that lag to predict. We have this performance in an experimental device; when will we see it as an operational device? This is a reasonable way to forecast. The gap dropped from about 10 years to about 6 years in 1950, and it hasn't changed much since. That is one way to use leading indicators. However, the most frequent use of leading indicators is looking for discrete events which foretell something.

Here is a list of important events in the history of atomic energy. Here we have a scientific breakthrough, mass and energy equivalence, for which there could not possibly be a forecast. But once that scientific breakthrough is available, it took us 40 years to get the actual technological breakthrough of nuclear weapons and 51 years to get the breakthrough of commercial electric power. There were plenty of clues in here as to what was coming. The trick is to make use of these clues to get a better estimate of the timing. Once you have mass energy conversion as a theory, then at least it is reasonable to say that someday we will get atomic energy, someday. When is that someday? You have to look at what is happening, what are the clues, and forecast the dates.

This is the front cover of a novel which first appeared in Liberty magazine in 1940. The novel describes a war between the United States and Germany, Japan, and the Soviet Union on the other side, and I would argue that two out of three isn't a bad batting average. In the novel, the war begins with a combined Japanese/Russian carrier attack on Pearl Harbor, and ends in 1945 with a U.S. aircraft dropping a uranium bomb on a target in the Soviet Union. I say again, this was written in 1940. In 1940 the information that I have shown you on this previous chart was already well enough known that a novelist, not even a scientist, could get the year right and get the isotope of uranium right. The information for doing leading indicator forecasting was there and some people, at any rate, were using it.

Arthur Clark, one of the world's well known futurists among other things, has listed some problems which one encounters when one is trying to do this kind of leading indicator forecasting. I believe it's worth mentioning them. The first is failure of nerve. This is when you get all the facts right, and you don't have the courage to follow them to a conclusion. Failure of

imagination is when you get all the available facts, but lack the imagination to see that the really important facts are not yet available. These are the two pitfalls that the technological forecaster must worry about in trying to use the leading indicator method of forecasting.

I'm going to step over the causal model method for the simple reason that we don't use it. The reason is we don't understand the sociotechnical economic system well enough to say what are the elements, what are the interactions, and to model them. We do, however, make some use of stochastic methods.

We had a question earlier about the intervals between breakthroughs. It has been demonstrated that the incidents of innovation can be described by appropriate probability distribution. One researcher found that both invention and innovation (commercial introduction of an already existing invention) were described by negative binomial distributions, and the lag from invention to innovation was described by a Pareto distribution. Another research line found that the occurrence of breakthroughs was described by a Poisson distribution, and the interval between breakthroughs was described by an exponential distribution. However, these results are new, within the last five years, and they have not had significant application.

The only real application we have made of stochastic methods is illustrated by a sample. This is a histogram showing the output of a cross impact model which is a kind of discrete, event-oriented simulation model that is widely used in technological forecasting. What this is saying is that in a set of simulation runs, in this many out of a total of 100 runs, the use of fiber optics for 90% of all long distance calls occurred. That's the event -- use of fiber optics for 90% of calls. It occurred in the different simulation runs with these various frequencies. In about 12 cases in 1988 and something like 3 cases in 1989, and over 30 cases in 1991. This is the kind of information that you would get out of a cross impact model, and this stochastic information then can be useful to say that we don't know exactly when it is going to happen, but based on all the information we have put into the model, this is the probability distribution for that event. You can

expect it the earliest here, the latest here, and some kind of distribution in between.

I don't know that I have encouraged you to believe that you can forecast with confidence, but at least I hope I have led you to believe that there are some systematic ways that you can take the knowledge that you have about the past, apply the appropriate one of the four change laws to that data, and get yourself a reasonable forecast of what technology might be available in the future.

Question (Zacherl): On your graph of project complexity and costs, have you looked at the SDI project?

Martino: No, I haven't had a chance to update the graph, but I also don't have a cost estimate for SDI.

Question: Have you tried it both ways - using complexity to estimate the cost and the other way around?

Martino: Yes. In fact, I have used this in the past for that sort of thing. When somebody says here is a project and it will cost about this much and we should be able to finish it in 19 umpty ump, I look on my graph and say that it is at least possible that you can manage a project that big by that year, or that it will never make it because we won't know how to manage a project that big by then. It might be worth it applying it to SDI. I'm glad you suggested and I'll try to see what I can do with it.

Baker: If you have never seen some of the forecasting as far as the Department of Defense, I would suggest that you look at Norm Augustine's book that is called "Augustine's Laws." He does an extrapolation of the current cost of fighter aircraft and he concludes that in the year 2010, the defense budget will be able to afford a single aircraft. The Air Force will use it for two days a week, the Navy for two days a week, the Army for two days a week, and when it isn't down for maintenance, on the seventh day, instead of

rest, we give it to the Marine Corps. It's a good example of what you are talking about.

Question (Holz): You indicated on one of your earlier graphs on extrapolation the "failure" of the supersonic aircraft. Instead of regarding that as a failure, could not that be regarded as an initial point for the implementation of the new technology.

Martino: You're right. It was the initial point for the implementation of new technology, but the thing that was wrong was that they tried to introduce it commercially at a time when it was not ready.

Question: Plotting it against those criteria, I agree. But so long as it could be treated as a new technology, it might serve as another point.

Comment (Baker): In that regard, people might forget that at the same time that the Concorde and the like were being entertained as a joint venture by the British and the French, the U.S. had a thing called the SST, and they made a decision to no-go, based on those kinds of data.

Martino: I promised to show this one, then ran out of time, but it illustrates your point. Here we have aircraft speed. This is the growth curve for propeller aircraft and here is the growth curve for jets. Notice the intersection. There is no jump. The first jet aircraft were inferior in this measure of performance to their propeller driven contemporaries. However, they employed a technology that was inherently capable of getting above the curve on which the props were stuck. What you see here is a cross-over, which actually represented a continuation of the historical trend. Yes, the first implementation of a new technology is often inferior. When the Germans introduced the Henkel 178, they did it as an experimental aircraft. They didn't try to go in one step to a combat fighter.

Question (Holz): A comment in regard to your last point here. The comment was made this morning by Colonel Miller that either the Army or DOD has now decided to compress the time frame of the conceptualizations coming off the production line from 12 or 14 years down to four. I don't believe it. I

don't believe anybody seriously believes it, and I think it is probably doing a disservice. Nothing that I have heard thus far indicates to me that private industry is able to go from concept phase to bending metal and turning stuff out the doors of the factory in that short of period of time.

Miller: The British got an awful good radar to put on the aircraft on their carriers while the war was going on the Falklands, and they won the war, too. Industry can do it. They took everything off the shelf and chunked it together in a nasty looking old box and the first R&D was when the first guy took it up in his plane and he didn't get shot down. It can be done, and certainly it has to be done, or at least set out there as a goal. As long as we say we can't do it, we always have 100% surety that we will be right.

Hart: But isn't part of the answer to your question, Bob, is that the reason that growth curve is like it is is that the United States kept trying to put too many different technologies at the same time in one weapon system? The answer to the way you do the four years is to say that I am only going to make an advance in a couple of technologies.

Holz: I would also buy four years if you are talking items off the shelf. I would agree with that.

Baker: There is, of course, difference between new technology and mature technology. We have a lot of mature technology that can continue to improve.

Jahn: I'm curious about what you use for trend breaking criteria. For example, your commercial aircraft passenger growth curve looks like it includes the 757, 767 on up. This last curve that you showed does not acknowledge the fact that commercial aircraft are now contemplating returning to turboprop power plants. Clearly, both of those violate the pattern.

Martino: I gave one instance, in the case of the fighter aircraft, when the trends would show a weight and speed which was unrealistic, unreasonable for the application. In the case of the commercial transports, remember I didn't say that I was projecting speed or something like that. I was projecting passenger mile per hour productivity, which is an important economic

criteria. When they get these things that they no longer want to call propellers, but they are, it will be because it is a cheaper way to move passengers. It is a cheaper way to produce passenger miles per hour. As for the 757 and others, they are for comparatively shorter legs than the 747. The world aviation market just doesn't seem to have justified anything bigger than 747's, anything with a greater passenger mile per hour productivity. That is, in part, because the 747 came out just before the oil crunch, when all of airline economics changed.

We used to try to manage the economy through things like providing monopoly routes to airlines, and we got the results that any economist would have predicted. The price goes up and the factors of production capture that; the airline didn't make money off those high priced route. The pilots made money; $70,000 for being an airline pilot. What is going to happen is that the $70,000 a year pilot drove you to bigger airplanes. One $70,000 a year pilot can drive a big airplane, just as well as a little one. Now, we are going to see cheaper pilots and littler airplanes, because the economics are not driving us up. With deregulation and prices going down, the pilots are going to see less and less as their share of it, and we are going to see smaller and smaller airplanes.

<u>Baker</u>: I'm going to put my black hat on and draw this to a close. We need to know what workshop you want to be in tomorrow, so if you haven't given your form to Kerm, please do so.

FRIDAY, JUNE 14

Baker: Let's do a little summarizing of the things that occurred yesterday. We kicked off with an Army 21 presentation by Colonel Miller. Among the key things, from my bias, was that one of the major changes is in the arena of moving from a philosophy that was fundamentally defensive staged in a western Europe type environment, to an offensive, fast, dynamic environment with high tech emphasis. The question was what do we have in terms of technology, what does it portend for them and for us, in terms of getting the soldiers ready to fight this different kind of war? This gave us a kind of concept or framework to work from.

We go then to some of the technology. Jim McAlear had mentioned that the biochip is one of the major areas that permits a breakthrough. The old computer technology, he feels, will be left behind in the very near future, and we will escape some 40 years of a Van Neumann machine environment to a parallel processor environment, which was seconded by George Miller and others. We are in a transition stage now from the computer as we know it to a biochip, parallel processing arena. The other problem then becomes that, if you are into this type of processing, like "where is the beef?," the question becomes "where is the software?" Where are the programs that are going to run this?

Mike Gazzaniga talked about memory being a key aspect of the demonstration of intelligent behavior. I was struck by the fact that the data are on people with IQ's of 140 and better but they are amnestic, and their behavior doesn't reflect their capacity. Memory becomes a tremendous component in terms of performance, and performance is what we are looking for in that kind of dynamic and fast moving environment. While the trauma of amnesia was the focus of the research data he was talking to, in the subsequent discussion, it was pointed out the same probably holds for this kind of detriment from fatigue or chemically induced problems that you might have in chemical warfare situations. The search will be for possible things to off set this, which could be pharmacological, monoclonal; we don't know what the solutions are,

but we know that the technology is in process of trying to develop these. It is still a problem we have to face in this future world we are talking about.

Bob Finkelstein talked to us about robotics and AI, and he raised questions of the Strategic Computer Initiatives. I would like to add my own observation to this because Bob did spend a lot of time talking about DARPA and the SCI, and one of the problems we have to be aware of is that within the military, many times we look to DARPA, for example, as being the cutting edge. That was what they were put together to do, but we also tend to ignore independent efforts that are occurring in industry. Within the past month, I have talked to two industrial groups who have discussed with me, right now, the sorts of cutting edge changes that are occurring, one of which will be announced in September, that will be several years ahead of anything that DARPA has in the mill. In other words, if you are watching a DARPA plan that says the technological breakthroughs are going to occur in ten years, you don't have the luxury of that buffer time to do your planning, because, in all probability, the technology may be with you tomorrow. The pace of the technology changes today causes some real difficulty in terms of strategic or long range planning.

Bob was followed by George Miller, who talked about, among other things, computerized adaptive testing. These kinds of things make a lot of sense if the concern, which we know from Colonel Miller, will be in the changing quality and constrained numbers of the people in the Army environment in the year 2010. We need some better ways to assess, select, sort, and assign and computerized, adaptive testing seems to be one of them. I would mention an observation that goes with that. There is a certain social phenomenon that one must overcome. When I was with the Army Research Institute, we tried some computerized adaptive testing in limited applications for skill qualification tests and we ran into an interesting find. If you computerize adaptive testing, no two students take essentially the same test, that is in terms of exact items, but it is an equated test. What they were feeling was this problem of maybe I didn't do as well for promotional purposes because I didn't have the same test as another individual. There has to be a way of selling the equality of the testing and the challenge testing as being a good sorting tool for selection.

The other thing I would mention is something that George put a lot of emphasis on and it bears reiteration. The communications aspect was mentioned, but not mentioned a great deal yesterday. We focused so much on the computer that we forgot the communications aspect. I reviewed a paper about two years ago and it said something like in time, and I think that time is here, there is no longer a distinction between computers and communications, and the author collapsed the two into "compunications." I happen to like the term. Again, when I was at ARI, I told the commander, Colonel Cosby, that I wanted to call the group I had the compunications group, and he said "try to brief that one in the Pentagon." We changed it to computers and communication.

Of course, George also raised the issue that we are exploring in the training arena, ICAI, intelligent computer assisted instruction, and the networking notion that goes with the question of language problems that one is going to incur when you start training and networking people in these arenas. This presents problems even within our own country with the growth of English as a second language and the Hispanic community.

Bob Jahn then talked to us about essentially one way of breaking old boundaries to our thinking. Not accepting, for example, fixed and immutable certain natural or science laws as we know them, but leaving the mind open to taking a look at other aspects or other ways or dealing with the world and the phenomena of the technology around us. One in particular was the influence of the communication between man and machine, in a different way than we usually use people/machine communications, namely, sort of a psychokinetic influence. One can wonder, given the data that Bob presented on the influence that one can have on a machine, if the influence would be even greater in a biochip or biological type environment.

Connie Zweig mentioned to us a number of things that are in the current press. She point out that one should again consider breaking the boundaries, and she talked about feelings in learning, getting one up for or the emotions related to learning. I would mentioned one thing in passing. I've seen the data that's been looking at ball players and their having to change time zones when they travel across the country to play ball games. There is also a lot

of work being done on something called flux, that is when the individual is into a batting streak. It essentially seems to be that all systems or components are go. These are observations that can be made and somewhat quantified post hoc, but the question could be is there some way we could generate or bring people up into a state of flux that makes them perform best in a learning environment.

Henry Halff then talked to us about biotechnology research, and he made one strong observation -- one that makes sense, although it doesn't make people happy or have warm, fuzzy feelings. Biotechnology addresses very little of the cognitive or psych arena or much of the training arena. He also talked about the question of fidelity in simulation and simulators. That is a problem that has bugged the services for some time. Simulators now somethings cost more than the equipment they are meant to simulate. There is a strong press now toward generation of generic simulators, and with the AI type of programs we could use, there is no reason why we couldn't simulate, on line, a costly, high fidelity simulator before we bend metal, and consequently determine the best and optimal design we should use.

Finally, our closing speaker was Joe Martino, talking about forecasting and what it implies in terms of our looking out to the year 2010. As Joe mentioned, it begins with data, and requires a change law. Harking back to his discussion of leading edge indicators, Joe had one curve showing experimental aircraft when it came into the inventory, and a parallel curve to give you an envelope that talked about when it finally got adopted and was implemented. Many of the trend data and leading edge indicator data indicate six to ten year lag time. In our discussion, it was interesting to note that there is no equivalent that I know of for educational or training technology. When did computer assisted instruction or some segment of that technology get adopted or become part of our operating environment? Additionally, if we are talking about the Army in the year 2010, we have a combination of things we need to look at. That's the instructional and training R&D, which is like his experimental aircraft, and the applications of that R&D -- the actual training. What is the lag time? If the lag is 10 years, the R&D essentially has to be in final form by the year 2000. The year 2000 is 15 years away; if

it takes 10 years to develop R&D, then we have very little buffer time to get on with whatever we have to do in the year 2000.

Those are my observations and a sort of summary of what I thought were the key points of what was presented yesterday as a memory jogger. If I did terrible disservice to the speakers, don't beat up on me in public. I would like now to bring our technical sponsor up here who has some observations he would like to make, vis a vis what occurred but, more particularly, things that were not covered. Following Bob Seidel, Marshall Farr will make some observations and assign you to the workshops.

One closing comment is that yesterday was the time to listen and ask questions; today is the time to talk in your working groups, and produce answers.

Seidel: I just want to say that I appreciated everything that went on yesterday. It reinforced the need to have an awful lot of people give their best to this problem. If I sound negative about it, it is only because I'm emphasizing the gaps, rather than what we did here. I think what we did here was very, very useful and very good, but I heard a number of disconnects yesterday. One of the biggest disconnects was that we don't have a representative here, and I'll take the heat on that one, for sociological change. What we heard yesterday was a series of supporting technologies that will be available to help out in the year 2010 with an over-arching concept of a sociological military or a military sociology, which did not sound very much different. What made me think about saying this this morning was Joe Martino's statement yesterday that one of the problems with future forecasting is that people get a failure of nerve when they are led to inevitable conclusions. Well, darn it, for the last 30 years in terms of functional organization of the military, I think we have been somewhat inappropriately put together to handle things that occur. We had guerrilla warfare or those kinds of events in Korea, in Vietnam, in Lebananon, and yet when we hear the concept of Army 21, I hear more like a full scale war, I hear a large country against another large country, and somehow, to me, that inevitably means to me that we are getting into a nuclear confrontation. If that's the case, every

thing we are talking about this morning pales by comparison, and falls to insignificance. This is my bias, my point of view, but I think it is something you should consider, particularly when we heard COL Miller talk about functional force reorganization. One of the functional force reorganizations I think we should consider is how do we deal with these kinds of limited wars that occur and train for that and do a search on training for that. Maybe there are things going on behind closed doors that I don't know about, but I haven't heard anything about that.

The second thing that was lacking yesterday was talked about in one of the papers you have in your books. Mike talks about it in his paper, but we didn't talk about it yesterday at all, although it was implied by some of the difficulties we had when Jim McAlear talked about the capability for so many decisions per chip. Bob Finkelstein raised the question about the problem of the software, and other people made the commentary that intelligence is not made by having the capability, but indeed by putting the intelligence into the capabilities that we have, whether it is hardware or software. I am leading up to considering the need to consider research issues from interdisciplinary teams, and how would those be put together, and what implications does that have for the training research in the years to come. I didn't hear those issues at all, and I would like to hear us consider those, at least take it up in your group.

Another gap that occurred had to do with the difference between the researchers and the practitioners. I wish Frank Burns were here, by the way. I would consider him a practitioner and a guy who knows an awful lot about neural linguistic programming. The term itself doesn't mean all that much, but NLP is a way in which messages can be organized so that you can change belief structures, and you can indeed influence people, and it works. It is being used in management seminars, in the practice of psychotherapy, and very successfully. I guess one of the problems is that people are making an awful lot of money out of it, so we don't consider it something that we want to touch, perhaps. I don't know, but it is a disconnect between research and practitioner.

Lastly, appropos of another point that was raised, I have a bias also about the need for us to consider not just digital learning, which to me is the hallmark of the computer as we know it so far. From an early age, we have been taught how to write, how to read these little symbols, and I call this a digital kind of learning. What has happened lately is that with the capabilities for computer generated imagery and interactive videodiscs that can be made more cheaply and are more readily available, we have the opportunity to bring that analog or pictorial capability up to the same level of development and capability for development that we have concentrated on the digital. We see it couched sometimes in terms like imagery learning or imagery research, but again that bears in mind the notion that we need more than one kind of discipline involved here, and it also tells me that we may need a different form of vocabulary to deal with the issues we are talking about. Rather than say "compute" from now on, why don't we think in terms of "transforming." I don't hold that up as the only way to look at it; I'm simply saying that we may need some new looks at vocabulary and how to describe some of these efforts.

That's really about it. At this time, COL Cosby, who is our commander at ARI, would like to say a few words.

Cosby: If we haven't already, I think we ought to express our appreciation to the Army on it's 210th birthday. Happy birthday, Army, for those who are associated with that.

Let me ask you, in the next few hours we have here, to be bold. Cause us to stretch out; cause us to look at the future. Cause us to write a science and technology plan that truly reflects 25 years into the future. That's tough for us to do, but I've asked you to help us.

The Army Research Institute has about 1% of the Army's R&D budget, and we have to be very wise in how we spend that. The 99% goes for hardware, to include computers, both hardware and software, and a lot of weapons systems, etc. We have to be sure that we are spending our money on things that help people, because if we don't, nobody else does in the Army. By people, I mean individuals certainly, collections of people in units, organizations, and all

the rest. Let me try to answer the question of why we are focusing so much on automation here today. I think it's a natural. We're really talking about processing information and, in fact, that is all that all of us do here. It's been said, and I believe it, that the currency of the trainer is information. Our job as people researchers is to help process it a little faster, to cause true learning to take place in the heads of the people in the Army.

Let me also remind you of another thing; I heard a little of it yesterday, but not enough. What we do in war, and in industry as well, is much more important than how we do it. That says that you also have to pay some attention to decision makers. They decide what we do; they decide the strategy. A lot of people of lesser rank, maybe more important but lesser rank, carry out the tactics of that. As you look at technologies that can help people do their jobs, don't forget that senior people need help also. As a matter of fact, Frank Hart and a lot of us from the TRADOC community have said over the years that the need for training in the Army is directly proportional to rank. Again, because what you do is more important than how well, and they decide what.

I would ask you today, applying all you know and brought with you and all you have learned here, to help us structure the lazy-S technology curve. Help us get up here at some time 25 years in the future, but tell us what we ought to be doing down here. This chart is some kind of productivity over time. Help us down here. I see your structure of the work groups of I being about in the middle of the curve, II here, and III here. The wildest group is Bob Holz's group, group III. What we are asking you to do is to help us write our science and technology plan down in this area here, 6-1, 6-2, 6-3. What is going on up here is going on; we can't change it, probably don't want to change it, and certainly don't want to straight-line it. But help us down here on the lower part of that technology curve.

Again, be bold, stretch us, make us say "no" along the way. Don't try to give us what we want, because we don't know what the hell we want. That's what we got you in here for.

Baker: Marshall Farr will make a couple of comments, and then talk to the issue of the working groups to which you will be assigned.

Farr: I'm charged by the Allen Corporation, in part, with coming up with a document from these two days of meetings and other input we will use from prior meetings and other sources, which will be what COL Cosby just referred to - a document that can provide the basis for an actual Army Research Institute Training Plan for R&D. What will they actually put into effect in 6-1, 2, 3 programs in the Army Research Institute starting now in preparation for the 2010 era. What I want you to do when you break up into groups is to help me, and the Allen Corporation, by being as specific as you can with respect to that particular bottom line.

There are some points I want to make, which I hope will be helpful. There are several gaps which must be bridged between what was said here yesterday and what we need to come up with. I don't intend that you be the complete bridgers of that gap, but try to help us out as much as you can. The first gap is between technological possibilities and the role of the Army in the future. The role of the Army obviously is going to be function of cultural, economic, political, and other considerations in the year 2010. They will shape each other. The military and its needs will shape society and will be shaped by society. The second gap is jumping from the role of the military, the Army specifically, to its training needs. That may not be as easy as it seems, especially if somebody considers the role to be one of almost complete automation. What is there left for the human to do? Maybe he or she will simply be a command and control type, for the most part. Maybe we will have two types: the very lowly soldier who does the minimal skills of cook or bottlewasher, where there is no particular reason to convert to automation; it isn't cost effective. At the other end, we may have only generals and high officer levels who will make command and control important decisions. The in-between range will be handled by robots or some kind of automaton device, whether there is a man inside it or we use men to control it remotely.

From training needs which come out of what the future will look like overall, what then can an R&D program for ARI look like? We don't expect

those of you who are not researchers to translate training needs into R&D requirements. Frequently, some of the training needs that you might foresee are not amenable to R&D. They may be amenable to simply a stroke of somebody's pen who changes the way things are done. But if you can possibly extrapolate to actual R&D programs for ARI, please try to do so.

These exercises this morning will require a fair amount of mental discipline. We heard about how to augment mental discipline in these meetings. The tag on this cartoon is "Don't forget the little pads in case one of them has an idea." We are looking for ideas, and in order to get to those ideas, we have broken up the groups this morning into various places along a spectrum that we envision, ranging from essentially complete automation where the battlefield is predominantly or solely occupied by machines, to the other extreme where the human operates essentially in the same mode that he operates in today, but with augmented powers of the kind you heard about yesterday from Zweig and Jahn. That is, no external augmentation by mechanical technology or prosthetic technology. In between that, the other working group is positing the part of the spectrum where the humans will work synergistically with the machine, and in a sort of R2D2 kind of relationship -- an expert system robot all rolled into one, perhaps as large as a walking anthropomorphic machine to accompany each soldier, perhaps an expert system so small that it can be embedded in the head or carried in the pocket. The system can query, or serve as sensors, or possibly carry your munitions and spare parts. Those scenarios are spelled out in the instructions to each working group. Please try to keep within the scenario; it you think you have covered it adequately and still have time, give us your best thoughts on some in between scenarios, combinations if you will, that you think are workable.

I'd like you to consider the fact that technology is just a tool. We've heard a lot about it, and some of you here make your living by being technologists, for the most part. We heard some illusions to it yesterday as sort of being sacrosanct by itself; the technology of chips in the future will give us such tremendous memory capacity that machines can become intelligent by virtue of it. That's fine; machines need that capability to become truly intelligent, if they ever can. But, as we heard also, you need an architecture and you need software to go with it. The same thing is true of

any other technology. Technology is just simply a dumb beast at our service. We can use it in any way we want to, and political, social, and military influences will tell us if we will use it and in what way we will use it.

I'd like you also to consider things which were not mentioned very much. The future will bring counter issues; the enemy will change, our allies will change, the shape of their weapon arsenal and military systems will change. We have to adapt to that, and there was very little talk about that in the way of assumptions about how that would happen. Remember also that we should try to deal with all forms of warfare, ranging from full warfare to guerrilla warfare to anything in between. That can very well influence the role that the soldier will play. Somebody acting in a guerrilla mode without backup support, without central depots readily available to repair equipment, will be much more in need of an expert system to guide him or her in maintaining that piece of equipment, because they would be on their own for days at a time in the jungle, for example. If, in fact, there will be an infantry and if there will be that kind of fighting going on at all - another thing to consider.

Technology is a double-edged sword, at the very least. We've heard it talked about here as the weapon of the future. We can have pharmacological and chemical and biological weapons, and at the same time those very same ingredients can be used as mind enhancers. That again illustrates the fact that what we do with the material we have is important. It is always curious to me, being a behavioral scientist and working for DOD for many years, that psychology, a behavioral science, has been considered a support technology; it is classified as that. I look upon it just the other way around. The study of people who are the systems, who make up the systems, is the main technology. Ammunition handling and all the other computer technologies and mechanical technologies are in support of the human being; he or she is the one who is fighting the war, who decides to fight, who makes the ground rules and develops strategies and tactics.

Let's get to the details. You are going to break up into these working groups and the membership of those groups is shown on the door. There has been a change in chairmanship of these groups. We are making an ARI person the chair of each one, in the hope that that person can be depended upon,

since we have some leverage, to do the work and write it up and present it, and will be around in the weeks following as a resource. Two chairman have decided to swap for reasons only known to themselves; Bob Holz and Jim Fobes are switching. Fobes will be the chairman of group III and Holz of group I. Those leaders have the key to the rooms where you will meet and carry on your work.

Baker: We will start with the enhanced capabilities that was chaired by Jim Fobes. No dissenting votes, as I understand it; great equanimity, unanimity.

Fobes: We had a problem. We carefully read the assignment, the five or six things that we were asked to do. Superficially, they looked reasonable, but they aren't on a Friday afternoon. As far as how to enhance performance 25 years from now, we don't know. I'm not sure that we would know if we spent more time at it, but it is obvious that we will have to spend a great deal more time at it.

In the 20 minutes we have allotted to us. I'm going to talk about one line of inquiry that we agreed was a reasonable one, Bob is going to talk about a different one, and then we are going to have someone reframe the problem for us.

One area that seems reasonable is the area of neurobiology. We think that ARI should either have a staff member in house or hire some contractors as an ongoing activity to keep an eye on developments in neurobiology, specifically psychopharmacology, and that's the example I'm going to go through today. The example implies some immediate programs that could be undertaken, but I'm not really putting it up for that reason - it's just an example.

These are some of the target capabilities that the Army would like to address. We would like to enhance the ability to process information. We would like to do it more quickly and more accurately. We would like to be able to increase our ability to concentrate. We would like to sustain performance, and we would like to manage stress and pain as they degrade performance. There are no doubt a lot of other things we would like to do, but this would not be a bad start. Since we are psychologists at ARI, our emphasis would likely be on the psychological constructs underlying these. If we look at those four constructs, this is what it has to do with neurobiology. There are some classic neural areas that underlie these constructs.

Now, it just turns out that these biological areas contain a great deal of endorphins. Endorphins are chemicals that were discovered in the late 1970's. They are produced by the body, and typically their levels increase in response to stress. They have some opioid properties, oddly enough, such as analgesia and euphoria, similar to morphine or heroin. Not only do the concentrations within the central nervous system vary, but they tend to be highly concentrated in the four areas of the previous slide that are the biological basis for the four psychological constructs. In addition to their concentrations varying in the brain, endorphins have specialized receptors, and the distribution of those receptors also varies in the brain and are concentrated in those four, admittedly very large, neural areas. Now, how could all this help the Army, going back to the targeted capabilities?

If endorphins are involved in mediating things that lead to these capabilities, then it is likely that manipulating levels of endorphins will alter these abilities. So one type of research or program under the heading of neurobiology is to undertake an investigation of the extent to which endorphins are responsible for these. There are behavioral data indicating that they are involved in these processes. There are probably 30 to 40 different kinds of endorphins. Is it one? Is it many? Is it a ratio? You'd have to look at that type of question. Should they be increased or decreased? Some basic research to answer those questions would give you some information about how you can go in and chemically manipulate the brain to give you the targeted capabilities.

There are a variety of ways that you might do the manipulation, and do not exclude the possibility that this could be done on a voluntary basis. By using some kind of biofeedback mechanism, individuals can be taught to regulate their levels of endorphins as a function of brain area. If a rat can be taught to raise temperature in one ear and lower it in the other to obtain a food reward, who knows? Maybe even humans can learn such a thing. So this is an example of a psychopharmacological investigation.

Bob is now going to talk about active man/machine effects.

Jahn: It was roughly ten minutes ago that I was informed that I was going to summarize this portion of our discussions. I presume this was some penalty for being totally incomprehensible, or incredible, or both, in the points I was trying to make. This, therefore, will not be the most organized presentation I have ever made in my life.

We attempted to show yesterday that under certain controlled conditions, it appears that human operators can characteristically influence the behavior of certain random physical systems and devices in a statistically replicable, and indeed predictable, fashion. We also tried to show that under controlled conditions, it appears possible for human percipients to derive information by anomalous means about remote target locations. We finally attempted to show that the data we have in hand defy explication on grounds of any known physical models, but can be brought to some state of coherence by readdressing questions of experience or reality from a more fundamental basis, in particular by getting subjective, impressionistic, intuitive, archetypal concepts into the model of reality in an explicit and active way. The question becomes, in the context of this task group assignment, what are the implications in the very long range for military education and strategic practice? I feel very naked, standing on that narrow and specific a platform.

I think maybe it would help if I just replayed this viewgraph that I ended with yesterday where we proposed as a scenario for the future of education in general the supplementing of the very best aspects of our contemporary educational strategies with its linear, deductive, causal, reductionist, analytical, quantitative priorities, now to be computer facilitated even further, by an expansion of the philosophical perspectives and epistemological premises that underlie human experience. In particular, we propose the expansion of the localized, particulate imagery of human consciousness and its interactions to include possibilities of wave-like properties; a relaxation of the classical Newtonian concepts or space, time, locality, and so on; the inclusion specifically of the subjective, impressionistic, aesthetic parameters in an enhanced metric for the consciousness which would include both the physical and the consciousness parameters; and the recognition that

the dialog between any consciousness and any environment has to be an active thing, which makes the human a participant in the generation of the reality.

I think a large part of this can be transcribed into the military purpose, but we surely don't have time to design that here. Assuming that could be done, I think it is reasonable to ponder the possibilities that you would find over this 25-year period, an enhanced set of man/machine and interpersonal effects. I call them "active" man/machine effects and man/man effects because I couldn't think of any better words in the last 10 minutes. It is meant to distinguish them from passive man/machine effects, which is the kind we think about now where the man is here and the machine is there, but they are doing their own thing and not really influencing one another in any interactive fashion. Consistent with some of the results we showed you, one could look first of all and in the shortest term to the possible deliterious effects of an unhappy man/machine interaction where one's own equipment would malfunction for these reasons. You can call it a gremlin if you want. You can call it something more elaborate. But what would be implied is that some information processing element or system had entered into some sort of interaction with the human consciousness which it was supposedly serving and had gone whockers for one reason or another. We indicated yesterday that we suspect the possibility of such vulnerability in the very low level micro-processors that are involved in cockpit controls or very articulated, integrated computational systems where individual elements are now switching at only a few quanta of energy, and certainly any system that involves the random microelectronic unit such as our own noise source that are used as reference for signalling processing or whatever.

If one wanted to be more aggressive about it, I supposed you could look to deliberately screwing up your opponent's equipment by this mechanism. We did not report on this, but at the present time we are into a phase of experimentation we call "remote pk," an attempt to assess the dependence of these interactions on the physical distance separating the operator and the machine. We now are carrying on these experiments at transcontinental and global separations. It is premature to report on those results.

On the positive side, however, I think there is some optimism for predicating enhanced man/machine performance. A profitable resonance, if you will, between a man and his functional device, which leads to superior performance than you would anticipate treating the two partners separately. I don't want to trade very hard on anecdotal evidence here, but I think many of us will concede certain mystical bonds between a teenager and his automobile, or a secretary and her word processor or whatever that may transcend the usual experience, and we are looking to see if there is any credibility in that and whether there is any controllibility. Can we develop that active man/machine technology?

The same sorts of vocabulary can be used in the interaction of one person with another, the interpersonal effects. We presume that is involved in our remote perception studies, for example. We are also looking at multiple operator effects on our individual man/machine interactions, that is to say what happens when more than one operator is attempting to influence the machine at the same time and how are those signatures compounded? Again, with the same disclaimers and caveats to a long extrapolation, a long period of evolution of understanding and technical development, one could possibly look toward the enhancement of various paranormal communication modes in a more systematic way, the acquisition of information about remote targets in a more systematic way, and perhaps most important of all, the facilitation of extraordinary team functioning among groups of individuals who are committed to a single task. The resonance that might occur between members of a combat group or of a particular aircraft or sea vessel or whatever perhaps we already have some anecdotal evidence for in terms of athletic teams or any other group activity where some of the experiences may be claimed to transcend the linear superposition of individual ones. Perhaps we will grow to that.

All of this, of course, is very possibly a subset of a more generic question, namely the age-old role of intuition and horse sense in dealing with matters of substance. Again, I emphasize that the proposition would to be not to replace analytical and technological sophistication, which clearly must continue to grow, but rather to balance it with a little more generous and strategic application of human intuition, whatever that may entail. It might entail matching individuals to particular jobs in accordance with their

demonstrated capabilities in this regard, some form of education which would preclude suppression of this talent by an overcommitment to the analytical or linear processing, and at best might indeed even enhance it in some way, and then the design of tasks to place such selected and educated individuals in the most effective locations where this generalized intuition, this intuitive leadership or judgment that I think most of us acknowledge in the abstract, could be brought to bear in a more systematic fashion.

Henderson: I call mine a minority view, because I found that while many of the ideas were quite persuasive and interesting, the emphasis seemed to me should really be on reframing the program outside of the bounds of the Army as an institution. I find that in the work that I do, most single-mission institutions have this same problem at this particular point in time. It doesn't matter whether those institutions are nation-states or multi national corporations, or labor unions, or universities, or even if you look at the way the Pope is behaving today, the Roman Catholic Church. Their problems are beyond the scope of the institutional framework, and the only way they can come up with anything new is by remapping the problem, and making a larger context for the solution.

For example, politicians in nation-states at the moment know that most of the variables that they need to be able to manage their domestic economies have now migrated into the global economy and they don't have a very good map yet of the global economy. Generally, it seems to me that what happens is that these kinds of system-wide problems build up until there is some kind of restructuring that is experienced by each institution as a crisis. What I'm trying to get a handle on is that there are a lot of potential crises out there, and the only way we are going to get a better road map to anticipating those crises is to look at our own single-purpose institutions and see how they relate to the rest of the society.

I came up with a few ideas that seem to be very difficult to cope with. In other words, the whole problem of recruiting and the volunteer army and what that has done in terms of ghettoizing the Army. There is a need, there seems to me, to reestablish relationships with the rest of the society, so

that the rest of the society cannot just relinquish responsibility and push the dirty work off onto the Army and walk away. I don't have any plan for implementing that, but I'm sure that COL Cosby didn't mean that to be a constraint on identifying that it is a potential problem. Then, I mentioned that the Army is really very good at lobbying the Congress. Some people said that the Army wasn't good, but I just know, having been on the Congressional end of it for six years, that the Army is very good at that lobbying. They have a lot of goodies to give out, a lot of jobs to give out in congressional districts, and if they really set their mind to lobbying the Congress, they are one of the best institutions in the country at doing that, because I've seen them doing it. That's basically the direction of my minority view, and I would say even though I wasn't on the other panels, we might consider the same possibility with the emphasis on the technological fix within the organization, rather than looking outside at what we might do in the larger context.

Fobes: If I could just add one more thing. Some people feel that we may have some gee whiz developments in technology that will enable us to substantially enhance performance. Maybe we will be able to plant computers in the back of people's brains and maybe just an RS232 plug; we can plug whatever chips they need at the time. Maybe a lot of things. But some people thought that a relatively safe bet would be to enhance performance through initial selection of performers, which basically comes down to a draft. It was pointed out by COL Cosby that this is somewhat unpopular at this time. Anyone who really advocates that strategy, and it has something going for it, what you really need to do is come up with an implementation plan to somehow reinstill a draft or something like it so that we can enhance people's abilities through selection.

Farr: Are there training implications for this, TRL R&D?

Fobes: There are a number of psychopharmacological investigations TRL can have undertaken on their behalf; the potential exists that people can be

trained to regulate levels of key chemicals in their bodies. In the second series of man/machine interactions, it is conceivable that people can be trained in a defensive mode to protect their own solid-state circuitry, and offensively to attack other people's. Maybe even deflect the path of missiles that are under control of the chips. I don't know about the third one. I guess you are talking about re-educating society.

McAlear: I'm confused about your implications about the draft. What are you going to try to fill in terms of the need?

Fobes: If you need a large number of people who have intellectual abilities that typically correspond with a high IQ for example, you can either try and enhance the IQ's of the people that you already have, or you can go out and draft people who happen to have high IQ's. The people who like to enhance ability to selection, that's what they are saying. If what you need is a high IQ because that correlates with abilities that you want people to have, then go out and draft people with other IQ's.

McAlear: Let's consider that there are other alternatives in personnel recruitment. Traditionally, the draft has been used to supply cannon fodder. As far as the need for higher education, I certainly agree that the best thing to do is to bring someone in who is already highly education, but the idea of using the draft for this is a ghoulish idea if I ever heard one.

Fobes: You could pay great salaries to attract people. I make a better living through chemistry clubs so I may not be the best one to defend reinstating the draft. As far as drafting Ph.D.s, I doubt that the Army would want them.

Baker: We will work our way back up from the bottom now, and we will hear from Group II.

Haggard: I must say that after today's experience, the Army definitely does not want to draft Ph.D.'s. This is the augmentation group, and we started out looking at what the situation would be like, what types of augmentation for the individual, and deciding that these are the main types, and he will be working in a sort of fast-changing physical, psychological environment. Probably NBC fits into this as an extreme.

We didn't do too well on the individual. We started talking about what he would be like, and sort of went on to bigger and better things, because we couldn't tell what the difference would be between this year and 2010 as far as the individual was concerned. We were sure he would be a little more computer literate, but what did that have to do with what we were looking at, the type of literacy. All I know is we have an augmented individual in this environment. Then we looked at individual soldier characteristics. We will require a lot more mental and physical endurance. There will be long periods of operation under highly intense situations and endurance is going to be a big problem. Already, it is a problem. We are going to have a lot more flexibility with the soldier to work independently and to work as a member of fluid groups, fast-changing groups that will be constituted and reconstituted in different numbers, and to obtain a feeling of immediate cohesion with those groups that will perform at a very high level.

We also are going to have to require much more technical competence, maybe not in the depth of knowledge that he has to have on equipment, doctrine, and otherwise, but on just the number. We will require that soldiers operate a large number of types of equipment, and be able to switch back and forth between those types on very short notice. For example, in talking about the structure of the Army, if we have a light division, nobody assumes that if we go into a heavy war in Europe that the light division will stay in California for the duration. They are going to be picked up and thrown into that conflict where they will have to immediately, or after a very short time, operate heavy equipment. In the same way, if we go into a light area we will

be replacing from heavy divisions into light divisions and those people will have to go into the operation of that equipment. Officers and NCO's will be switching doctrines from heavy to light, from jungle to plane warfare. Unlike in the past with one piece of equipment and one doctrine, they will have to be trained in multiple doctrines, multiple equipment, and be able to learn them, retain them, sustain their performance in them, and switch back and forth fairly fast.

What we then listed that we looked for in technology is a number of improvements in what we have in existing technologies. Of course, computers are going to continue to develop in terms of software and graphics to go with that type of situation where we are presenting these different conditions. You have to have much more advanced simulations so we can simulate all of these conditions with some sort of realism, and be able to switch back and forth and not have a simulator for each possible condition. We have to increase our work in cohesion, how we put together groups. If you work for the Army, you know that we are having a little trouble with the cohort group because we don't know exactly what we are doing with them. If we are going to have a bunch of small teams or large groups that are fairly fluid switching back and forth, this problem will become much greater. We have to look at how you establish cohesion quickly within a group. And we are going to have to work with the management of stress, how to control it, how to utilize it as part of the performance.

The emerging technologies that we think will help with this are listed here. I don't know why I'm going through each of them, particularly when I get to "state-specific training." I guess that means that training for people from Kentucky will be different from training for people from New York. These are the technologies that we think we could begin to put money into. Determining particularly the variables, the attributes that underlie some of those types of performances so that we can begin to look at how to train with them. Early in our discussion, there was the idea that in many of these areas, we do not know the underlying physiological, psychological variables or factors or attributes -- whatever you would like to call them. To talk about training in the past and the present, we are talking about putting people in situations over and over again which include these, we think, and somehow

there emerges a learning through repeated experiences. It would be worthwhile, we think, to go back and put the money into more basic research on, for example, what the attributes of sensation are in the specific situations we are talking about and, therefore, what we have to try to control, reward, develop as we develop a man's sensory capabilities, or as we try to simulate those or enhance them. I don't think the Army knows what part of that scene you enhance for me to detect targets, what part for me to determine the mobility aspects of the situation, or anything else. Now, as in simulation, we can represent it in toto and we should look at those aspects that underlie each of these areas. That was the basis for our recommendations on emerging technologies - not just to look at the training technologies, but to look at the psychological and physiological variables that underlie these kinds of performances.

I would like to say that the committee did most of this; they did a wonderful job. Are there any questions?

Perez: When you talk about sensory perception, are you talking about things like night vision? I'm trying to figure out what specific clues to differentiate enemy tanks from . . .?

Haggard: There were two aspects of it. One was the hardware or whatever you want to call it to enhance those capabilities; yes, like night vision and so forth. The other that Dr. Dunne was talking about a lot more was to try to enhance the individual's capability to discriminate those types of things.

Perez: Was there any kind of time line about when these kinds of things might be developed?

Haggard: No. We got to that question, but we have no idea about time lines. However, the two charts are aspects of time because we have the current, improved and the future, emerged. Other than that, we didn't know when these

things might be available. You can't predict how long it takes to break through an area, I don't think, except we have the predictor on our committee who will be given that task.

Baker: It's kind of amazing. When I dropped into that committee, I haven't seen anything that bloody since the Graziano-Zale fights, and to have them come out with complete equanimity and coherence, I think they took something walking down the hall.

We will not hear from Work Group I, and it will be presented by the chair who was R2D2.

Haggard: Let's me say one more thing. I didn't intend to say any of those things. Brenda controlled me while I was talking.

Holz: I debated saying something very clever and cute, but I think it has all been said before. I began this morning knowing nothing about combat robotics. I end today knowing very, very little about combat robotics. As the person who was assigned the chair and also functioned as the recorder of our small group, I will take responsibility for the graphics and the content is basically the product of really four individuals other than myself.

I think you will be happy with our final output, Hazel, but perhaps for different reasons. Jumping to the conclusion, I think what we have in effect come up with as a possible proposal is that if the technological advances in other disciplines continue to move in the direction they appear to be going, we won't have to worry about having a volunteer force or having conscription. It will certainly not be ghettoized, because there will be no Army. It will be robots. Now, there may be some here whose best friends are robots, then we'll have a problem there.

An important point is that robots need not look like the manned systems they are designed to replace. There is a mindset, and I'm as guilty of it as

any other. We think of a robotic tank and in our minds we have a notion of something that looks like a tank, but is not piloted or operated by a human being. Or an aircraft that is a robot aircraft, but it looks like an aircraft. In the remarks I will make, we are not necessarily speaking about robots that look like the systems they are designed to deal with.

Bob Seidel provided certain assumptions. We could argue these until the cows come home, but we tried to deal with them. The basic one is that robots, by some time in the future, 1999, 2010, 2100, - I don't know what time frame Battlestar Gallactica is, but that always strikes me as the ultimate in robots, and I'll say something personal about that at the end -- but there is a general consensus that the technology in terms of computers and mechanical engineering and basic design structure exist now, certainly, and will in the future exist whereby robots will carry out those tasks currently performed by humans. On the future battlefield, humans will not be present, but will monitor robots - that is a possibility. We might conceivably have robots of a higher order magnitude monitoring other robots. Then there will be intelligent interfaces characterizing humans and robots or robots and robots. Those are certain basic assumptions.

We spent a great deal of time discussing the issue of what sorts of situations or conditions involving military conflict might robots be found to engage in. One very obvious one has to do with the high-lethality battlefield envisioned in various Army publications and doctrine as pertaining to western Europe. It is going to be noisy; it is going to be dirty; there are going to be phenomenal amounts of different ordnances used, either conventional, or nuclear, chemical, biological, or radiological. That proves an ideal ground for robots. At the other end of the extreme, there may be other types of military intervention requiring U.S. forces acting in concert with robots or mechanical add-ons - insurrections, guerrilla warfare, explorations -- as well as in terms of surveillance and intelligence data. In many respect, what we tried to do here is to come up with a notion of robotics and their utilization in the military as falling along a wide ranging continuum.

Increases in robots and robotics, and the degree to which robotics can be made more cost-effective as well as perform to higher and higher demands,

could conceivably lead to not only a reduction, but an elimination of today's ground combat soldiers, as well as support soldiers. So you end up with a force basically robotic in nature. There are some positive and some negative aspects to that.

We considered the prerequisites for robotics fielding. If we are going to field "smart" robots, then we are going to need, as Bob Seidel indicated this morning, some sort of an interdisciplinary or multidisciplinary approach. We are also going to need a critical mass in terms of dollars. Army Research Institute, I personally do not view right now, in terms of current or short term funding profiles as necessarily being the center for R&D in robotics. I don't think you can get there with a million bucks a year. It's going to take a lot.

There is also a question as to the willingness of the current senior "leadership," civilian as well as military, to consider alternative organizational structures, manning philosophies, grade structures, on, and on, and on, along with the concept of robotics. There are more generals in the United States Army today than there were in World War II. We now have generals who are performing things that we used to assign to lieutenant colonels and colonels. We've become much more specialized and fragmented. We have to find jobs for a lot of high grade people. If we end up fielding a large number of robots, I think some of those high grade individuals are going to be put into a position of being asked what they have done for their country lately, moreso perhaps than they are being asked today.

Moving into the question of research and development in education and training within the Army, I think what we came away with was a notion that robotics will probably flow from much more complex to much more simple kinds of systems. Some of the surveillance systems, the remotely piloted aircraft, already exist today. The Marine Corps has a platoon of remote-piloted aircraft vehicles based on the Israeli models; there are land vehicles currently in development for testing; utilization of robots for loaders for artillery pieces; and possibly at some point further in the future, robots getting down to the level of the proverbial "grunt," the infantryman.

The training of people to both operate and maintain robots may well require specific skills and capabilities that we do not now have and that we do not now know about. It may well be that while increases in robots could drive down the total number of personnel needed to "man" the force, the remaining personnel that are required for maintenance and to serve as operators and man-in-the loop systems with robots in their initial phases may need such skills and the nature of those skills may be in such short supply throughout society, that the cost to the Defense Department of recruiting and retaining such individuals may cost more than the total force costs right now.

Some specific education and training R&D issues that we attempted to deal with here include again the dollars to support the research, the status of technology - not just in the behavioral sciences, but across the board in a wide range of disciplines, training applications for non developed items. I criticized COL Miller yesterday for the concept of four years from concept development to operational prototype. If we are dealing with off-the shelf items, we can probably do it. If we are talking about something that doesn't exist, I think that it is highly questionable.

Organizational concerns that we attempted to list and not really grapple with in great detail were questions of what types of personnel and what types of grades will we be required to bring in to deal with increasing number of robots, what are the technological costs and reliability of the system, and what are the vested interests? Organizations operate frequently on the basis of their own interests and where they are coming from; psychological concerns, economic and social issues need to be addressed.

Some of the implications of the "robotics movement" again may turn up new skill categories, fewer personnel, different educational/aptitude requirements, and we may well need to address changes in the total organizational structure of the force.

We took a cut at a time line, looking here at robotics research and development from the perspective of the Institute. Late 1980's to mid 1990's, basically training of human operators to deal with relatively simple robots robots that would be involved in diagnostics and maintenance. As other

technologies evolve, and we move into mid term 1990's to 2000, something called RBT - robotic based training - could replace the drill instructor in basic training. You want to have somebody really teach the soldier how to fire his weapon, use a robot. You'll achieve a high degree of standardization. You won't have to be concerned about the emotional views of the DI in relationship to the soldier. Robots are color blind. Longer range, we get involved in robot/robot training, consider utilizing robots to actually simulate opposing forces, war game them and do it in real time, mount a robot force at NTC. Try out new concepts. Robots presumably are able to process, synthesize, and communicate back much much more rapidly certain critical information, both "observable" and potentially non observable through all of their sensors. We may be able to learn something from all of that.

We took a cut at something called psychological research and robotics. The Army Research Institute is principally made up of psychologists, myself excluded. One of the issues or opportunities that was raised was the relationship between the human and the robot, how people tend to anthropomorphize existing robots. "Isn't that cute?" "Don't tease the robot; it's only doing it's job." There may be also a basic psychological reluctance on the part of human operators or people who have to interface with robots to deal with a robot, from a psychological perspective, that may need to be examined. Pattern recognition and perception issues as pertain to robotic abilities is one thing we know from human learning and human perception that can be applied here. The whole AI arena, the design of the expert system. Yes, a multi disciplinary research approach is probably needed here, and that may have some implications for the Institute in terms of not so much long range planning in terms of research, but in terms of personnel. Rather than have a staff of principally research psychologists, we may well wish to start looking to bring on board individuals from other disciplines to be part of the organization.

Depending on your view of the cup half full or the cup half empty, we have some opportunities. There was a consensus that we probably need to establish a central group, activity, agency to serve as a coordinator for robotics R&D. We need to identify a spokesperson for resources to conduct research on robotics. Whether that's at DOD or at some other level, I don't know, but one

probably needs a spokesperson with some degree of stability and continuity to avoid the perennial either every four year or annual peaks and valleys in the funding profile.

There is a real concern about the nature of research conducted on robotics from any disciplinary perspective in terms of if such research becomes more and more "successful," whatever the criteria of success are, are we not increasing the likelihood that such research is going to end up being stamped "classified"? What are the implications of that? We are probably well advised to seek linkages in terms of research in the private sector and other government agencies. The Labor Department uses robots to open mail. EPA, in some areas, seems to use robots to clean up hazardous spills. The medical community needs to be very involved in robotics in the design and manufacture of prosthetics. We also need to have an ongoing program to educate the leadership - our own, as well as Army, as well as DOD - - in terms of further opportunities.

This is something I made up after sitting here for a few minutes, so my colleagues haven't seen it, but I've tried to address some other issues that are indicated by dashed lines. One thing we did discuss was vulnerabilities of increasing robotics. Electronic warfare, nuclear, and as was pointed out by Group I, human interference. Another issue is whether or not countermeasures to increasing robotics will be acceptable. It is highly unlikely that if the United States decides to mount a major program to replace humans with robots on the "central" battlefield that our potential adversaries will sit back and do nothing. Another issue is whether robotics R&D really should be carried out by the military at all? Is it appropriate, or is it something that should be left up to private industry? And if industry can make it work, then maybe there can be some subsequent military applications. It's really a question of who should be in the forefront.

Then I've kind of tossed in for the hell of it, being a sociologist by background, that there seem to be certain moral and ethical questions regarding moving in the direction of increasing robotics and increasing reliance on machines to, in effect, do the job of humans. One of the concerns that I have here is that we all seem to be moving more and more towards a

position of "we are going to use technology to win." We seem to be relying less and less on such things as efforts to deter confrontation through diplomacy, through education, to opening lines of communication, as opposed to building the walls higher and higher and using technology.

Those are, in some respects, the views of myself and my colleagues. If any of them would like to make further comments, I'm sure they can fill it in far more eloquently than I can. If there are questions, we will try to entertain them.

McAlear: I'm not in a position of presenting a white paper. I did write a paper that was passed out yesterday which has a different emphasis. I think that Bob Finkelstein and I agree for about 10 years and then we diverge. Where we diverge is largely based on perceptions that microelectronic capabilities are going to continue to increase at a higher rate than they have in the past decade. I think this will have the effect of reducing the time of what we refer to as the sixth generation of computers being applied to robotics. We will penetrate the barrier of having something that is as intelligent as a man in the fifth generation and by the sixth generation, have something that is more intelligent. I think this provides a different kind of robot in the context of the chair's last remark, it also has different implications, more so indeed, to the future of man. The other point that I would emphasize is the suggestion that came up during the meeting that there is very little likelihood that the Army and the Congress or whoever is going to buy this kind of thing at this time. It is not reasonable to expect it. But I do think, because of the implications, that the idea that a group be formed that has some continuity and responsibility for information in this area is a sound one at this time.

Baker: I'd like to make just two quick passing statements about the robotics. With my bad memory I forget which of Isaac Azimov's sci fi books had the rules for robots, but I recall that one of them was that a robot shall never hurt a human. When we talk about using them on the battlefield, it flies in the face of those rules. There is another book that I would

recommend if you haven't read it: Sherrie Terkel's book called "The Second Self," about automation and our society. She wrote this at MIT recently. She is a clinician who started to look at AI and computers in that kind of context, and was surprised to find out that many of the people referred to their peripherals, and it took her a week or two to discover that they were talking about their spouses. She did a very neat job of critical analysis of children playing with computerized games and with electronic toys, one of which is a wizard box that plays tic-tac toe. Built into the box is the capability that every eighth time, there is a purposeful bug in the program that permits the thing to make a mistake so that the kids can win. She did a tape recording of two kids arguing and one of them said "That damn thing cheated," and threw it away. The other kid said "It can't cheat. You have to know and feel to cheat, and it doesn't know and feel." "How do you know that it doesn't feel that I threw it away?" They went back and forth about this, but we lose track I think of the fact that more and more children are seeing the world in a heuristic way and there is no sharp way to define their values.

What I want to do is to close out on three points, but I want to give an opportunity to Bob Seidel to give some closing comments, or Marshall, if you have something?

Seidel: I don't have a lot to say at this point. I just wanted to thank everybody, and I appreciate the impossible task that you had. First off, it is interesting that if you take a look at the three groups, I was not especially surprised at the way the results came out. Those that had the most difficult job were those who were dealing with the currently fuzziest topics today, enhancement of human capabilities. The interesting thing that came out of that certainly in the visit I made to that working group and their report was that I guess when people get into a situation that is particularly difficult and strains their current belief structures, what they do is to fight even stronger to retain those belief structures. I'm not surprised that we had at least three particular points of view expressed; I think there were as many points of view as there were people in the room.

The one that came out last, which was also gratifying to see and somewhat predictable, was the one that was most structured in terms of technology and the one that is most advanced in that respect. Indeed, we got the most satisfying sets of questions taken care of and answers provided, even though it was still very difficult to come up with any kind of specific projection. The ones that had the interesting, ambiguous task with augmentation dealt with the problem of uncertainty in a somewhat opening-up way, but they still came out with the tension of the old beliefs.

Having said all that, I've stolen something from Marshall which I will put on in a second that I think is a capstone for wherever we are, and helps us realize what long-range planning consists of. Every so often, I remember a joke, and it reminds me of that story of the guy who was going to buy his mother something to keep her company when she was living by herself, and Mother's Day was coming up so he wanted to surprise her with something unique that would keep her company. In a pet store, he came upon this parrot that spoke six languages, rather expensive, it cost $3,000, and he thought it was a wonderful idea to surprise his mother, so he sent it off to her. Three weeks later, he showed up at her front door to surprise her with a visit, and said "Mom, here I am. How did you enjoy the parrot?" And she said, "It was delicious." "How could you do that? It was expensive; I got it to keep you company. Do you realize it spoke six languages?" And she said, "If it was so smart, why didn't it speak up?" I hope everyone has had a chance to speak up and say something at this conference, even if you haven't had agreement with your point of view. If you haven't spoken up, that's your problem. The one thing you have given me is a great deal of humility about long range planning, and I thank you.

Baker: I think that fairly well sums up most of the things we have had to say today. I would like to take one moment though, and to put things back into a humanistic perspective. Many of the things we do as enhancements do not work out as we would like, and we must always remember the human frailties are maybe there for a purpose. Maybe we can push people over the deep end. I had an instance to remember one time where a woman went to see her doctor. She was feeling very badly, and after a complete workup, the doctor said "Well,

madam, you are pregnant." She said, "I can't be. I'm 76 years old." He said, "I don't care how old you are, you're pregnant." She said, "It's impossible. The only man I've ever known is my husband and he's 92." The doctor said "I don't give a hoot about that, lady. You are pregnant." She said, "May I use your phone?" She called up and got her husband and as soon as he picked up the phone she said, "You damned old fool. You've gone and done it now. You've gone and gotten me pregnant." There was a long pause, and the man said, "To whom am I speaking?" So enhancements may work in one regard, but human frailties are still with us.

The other thing I would like to say is that one of the bennies of working in this kind of environment is that you get to meet such neat people, such bright people, such stimulating and interesting people, and it has been my pleasure to have worked with you. I would like to take a minute to thank Kerm Henriksen who has been jumping back and forth and round about, and has done a fantastic job.

The only thing I can tell you now is that there is no way to stop the future or the things that will occur because the future, as George Allen used to say, is now. Things about you will take hold and drag you kicking and screaming into the future, whether you like it or not, so I would just like to say thank you for coming.

APPENDIX:

VIEWGRAPHS AND DISPLAYS

DR. ROBERT SEIDEL

Opening Comments

LONG RANGE PLAN FOR TRAINING RESEARCH

OVERVIEW:

STATEMENT OF THE PROBLEM:

RAPIDLY CHANGING TECHNOLOGY AND THE DECLINE IN AVAILABLE MANPOWER POOL WILL IMPACT ON THE WAY TRAINING IS CONDUCTED BY THE TWENTY FIRST CENTURY (2010)

SOLUTION:

TO ANTICIPATE THE INFLUENCE OF DECLINING AVAILABLE MANPOWER AND INCREASED SOPHISTICATION OF EQUIPMENT. TRL HAS COMMISSIONED A GROUP OF SCIENTISTS AND FUTURISTS TO DEVELOP CONCEPTS PAPERS TO IDENTIFY EMERGING RESEARCH AND TECHNOLOGICAL ADVANCEMENTS THAT POTENTIALLY WILL IMPACT ON TRAINING.

LONG RANGE RESEARCH PLAN FOR THE TRAINING RESEARCH LABORATORY

GOALS: TO DEVELOP A LONG RANGE RESEARCH PROGRAM FOR THE TRAINING RESEARCH LABORATORY

OBJECTIVE

- o TO DEVELOP A LONG RANGE RESEARCH PLAN FOR THE TRAINING LABORATORY
- o TO IDENTIFY EMERGING TECHNOLOGY AND RESEARCH DEVELOPMENTS THAT HAVE POTENTIAL FOR IMPACT ON ARMY TRAINING
- o TO CAPITALIZE ON EMERGING TECHNOLOGY AND RESEARCH DEVELOPMENTS THAT HAVE POTENTIAL FOR RESOLUTION OF FUTURE TRAINING NEEDS AND PROBLEMS
- o TO PROVIDE DIRECTION AND FOCUS FOR TRAINING RESEARCH SCIENTISTS FOR TRANSLATION OF THESE TECHNOLOGIES AND RESEARCH TO MEET FUTURE ARMY NEEDS

APPROACH

PROCESS

TO ACCOMPLISH THE GOALS AND OBJECTIVES REQUIRED TO DEVELOP A LONG RANGE PLAN FOR TRAINING, TRL HAS PLANNED THE FOLLOWING TASKS:

- IDENTIFY AND COMMISSION A GROUP OF SCIENTISTS AND FUTURISTS TO WRITE PAPERS IDENTIFYING ADVANCES IN THE FIELDS OF:
  - NEUROSCIENCE
  - BIOLOGICAL ENGINEERING
  - PHYSIOLOGY OF LEARNING
  - COGNITIVE SCIENCE
  - INSTRUCTIONAL TECHNOLOGY
  - TELECOMMUNICATION
- PAPERS WILL DISCUSS THE INFLUENCES OF THESE ADVANCES ON:
  - ROLE OF EDUCATION AND TRAINING IN: INDUSTRY, GOVERNMENT, AND MILITARY
  - SOCIETAL INSTITUTIONS: FAMILY, RELIGION, ECONOMIC SYSTEM, WORK FORCE

PROCESS (CONT'D)

- SMALL WORK SHOPS TO REVIEW VISIONARY PAPERS BY ARMY TRAINING TECHNOLOGISTS TO DEVELOP SCENARIO OF FUTURE TRAINING NEEDS BASED ON PAPERS
- REVIEW OF PAPERS BY SCIENTISTS IN SIMILAR FIELD TO INSURE COMPLETENESS AND CONSENSUS OF PREDICTED ADVANCES
- SYMPOSIA TO DISCUSS CONTENTS OF PAPERS AND SYNTHESIZE AND INTERGRATE FINDINGS: PANEL WILL CONSIST OF INDUSTRALIST, MILITARY TRAINING SPECIALISTS, AND SCIENTISTS

INTERNAL REVIEW:

- REVIEW OF PRODUCTS OF SYMPOSIA BY IN-HOUSE SCIENTISTS
- TRL, BASIC RESEARCH, AND PP&O

EXTERNAL REVIEW:

- RESEARCH PLAN WILL BE FORWARDED TO EXTERNAL REVIEWERS WITHIN THE ARMY FOR COMMENTS AND SUGGESTIONS
- TRADOC
- DCSOPS-TRL

ARMY 21

- ARMY ENVIRONMENT
  - FEWER PEOPLE (OF MORE DIVERSE QUALITY)
  - INCREASING TRAINING TIME AND COST
  - INCREASING EQUIPMENT SOPHISTICATION
  - INCREASING DEPENDENCE ON COMPUTER DRIVEN SYSTEMS
  - INCREASING DATA OVERLOAD (OPERATION AND MAINTENANCE)

- BATTLEFIELD ENVIRONMENT
  - COMPRESSED TIME
  - INFORMATION OVERLOAD
  - DISTRIBUTED BATTLEFIELD
    - • • FEWER PEOPLE
    - • • INCREASED SPAN OF CONTROL

IMPLICATIONS OF ARMY 21

(REQUIREMENTS)

- MORE ACCURATE FASTER METHODS FOR ASSESSING ABILITIES AND SKILLS
- INCREASE INDIVIDUAL'S ABILITY TO LEARN
- INCREASE INDIVIDUAL'S ABILITY TO OPERATE AT MORE ABSTRACT CONCEPTUAL LEVELS
- SOLDIERS TRAINED IN MULTIPLE SKILLS
- FASTER, LESS COSTLY, MORE "GENERIC" TRAINING
- LOWER RATING OF TRAINERS TO TRAINEES
- RELIANCE OF SIMULATION FOR TRAINING
- MACHINE ASSISTED ("EXPERT") PROBLEM SOLVING (MAINTENANCE) PLANNING/DECISION-MAKING
- MACHINE PROCESSING OF INFORMATION (REAL TIME)
- DISTRIBUTED INFORMATION PROCESSING AND DECISION-MAKING
- GROUP DECISION-MAKING
- COMMAND AND CONTROL NETWORKS (COMMUNICATIONS/INFO SHARING/PLANNING/DECISION-MAKING

WORKSHOP ON EDUCATION AND TRAINING

IN THE U. S. ARMY BY THE YEAR 2010

FORECASTING BY CIVILIAN SCIENTISTS

ASSUMPTIONS OF ARMY 21

COMMENTARY BY ARMY TRAINING EXPERTS

2010 SCENARIOS

ARMY RESEARCH INSTITUTE RESEARCH AND DEVELOPMENT PROGRAM

SYSTEMS RESEARCH PLANS

TRAINING RESEARCH PLANS

MANPOWER AND PERSONNEL RESEARCH PLAN

PEOPLE

THE VISIONARIES COMMITTED TO WRITING PAPERS ARE:

- DR. GEORGE MILLER - PRIMARY WORK ON COGNITION AND LANGUAGE, CURRENT WORK ON THE EVOLUTION OF THE INTELLIGENCE TEST (COGNITIVE PSYCHOLOGY, PRINCETON UNIV)
- DR. MICHAEL S. GAZZANIGA - PRIMARY WORK, ARCHITECTURE OF BRAIN, HEMISPHERIC PROCESSES (NEUROPSYCHOLOGY, SUNY)
- DR. PAUL LEVISON - SPECIALIZED IN THE IMPACT OF MEDIA ON INDIVIDUALS AND SOCIETY, (SOCIOLOGY, NEW SCHOOL FOR SOCIAL RESEARCH)
- MS. MARLYN FERGUSON - NOTED SYNTHESIZER OF NEUROSCIENCE, EDITOR OF BRAIN MIND BULLETIN, AUTHOR OF "AQUARIAN CONSPIRACY" (SCIENCE JOURNALIST, SANTA MONICA, CA)
- DR. ROBERT JAHN - CONCERNED WITH THE POTENTIAL USE OF HUMAN CONSCIOUNESS ON THE PHYSICAL WORK (PHYSICIST, PRINCETON)
- DR. LISA CARLSON - SPECIALIZING IN THE USE OF TELECOMMUNICATION IN SOCIETY (CONNECTED WITH THE WORLD FUTURISTS SOCIETY, WASHINGTON, DC)
- DR. HAZEL HENDERSON - CONCERNED WITH THE IMPACT OF TECHNOLOGY ON FUTURE WORLD ECONOMICS, (ECONOMICS, FL)
- DR. JAMES McALEAR PRIMARY WORK DEVELOPMENT OF THE BIOCHIP (MICROBIOLOGY, GENTRONIX LAB, MD)

VISIONARY SYNTHESIZER:

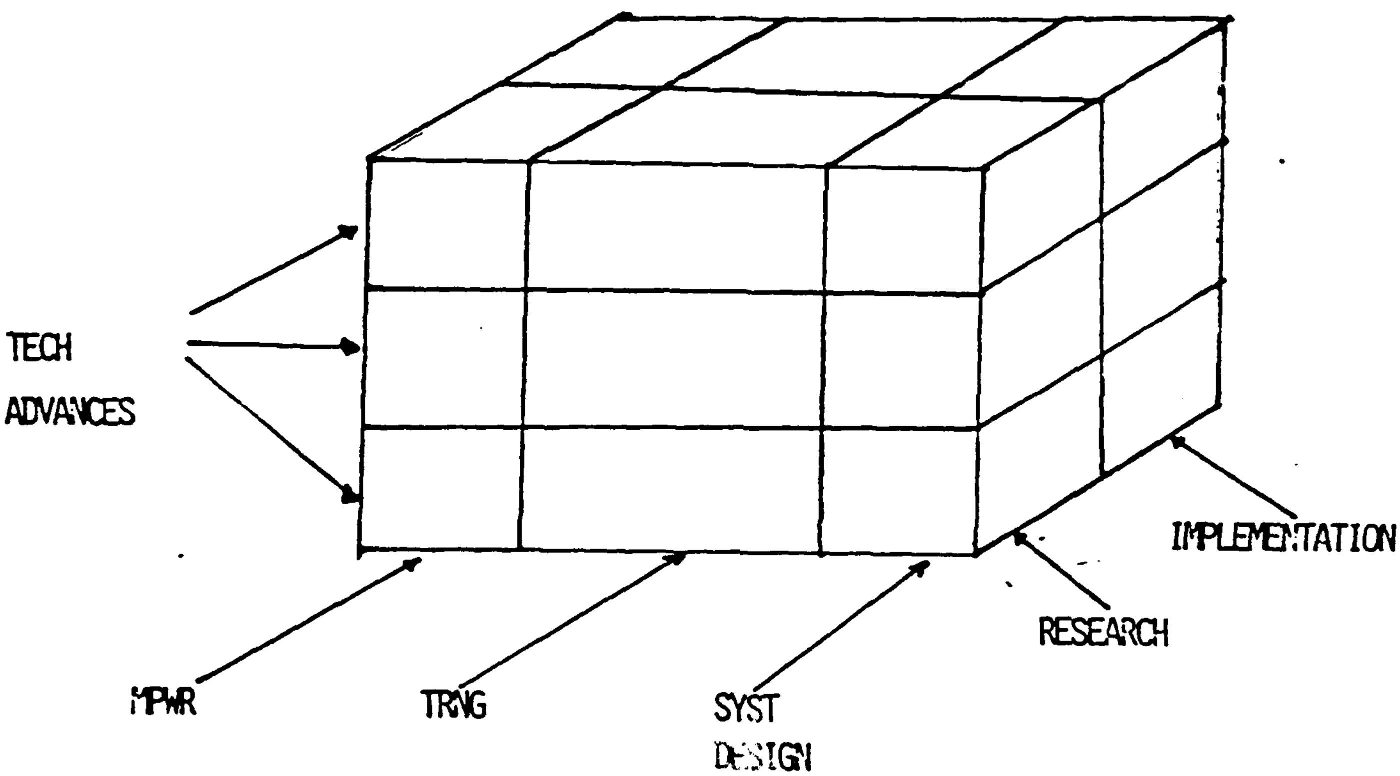
- ISAAC ASIMOV

FOCUS:

LIST OF TECHNICAL ADVANCES

IMPACT ON ARMY TRAINING

RESEARCH ISSUES



IMPACT

COL DAVID L. MILLER, JR.

Army 21

190

AN ARMY IN TRANSITION

- NEW DOCTRINE
- NEW EQUIPMENT
- NEW ORGANIZATIONS
- NEW MANNING SYSTEM
- NEW TRAINING CHALLENGES

HEADQUARTERS
TRADOC

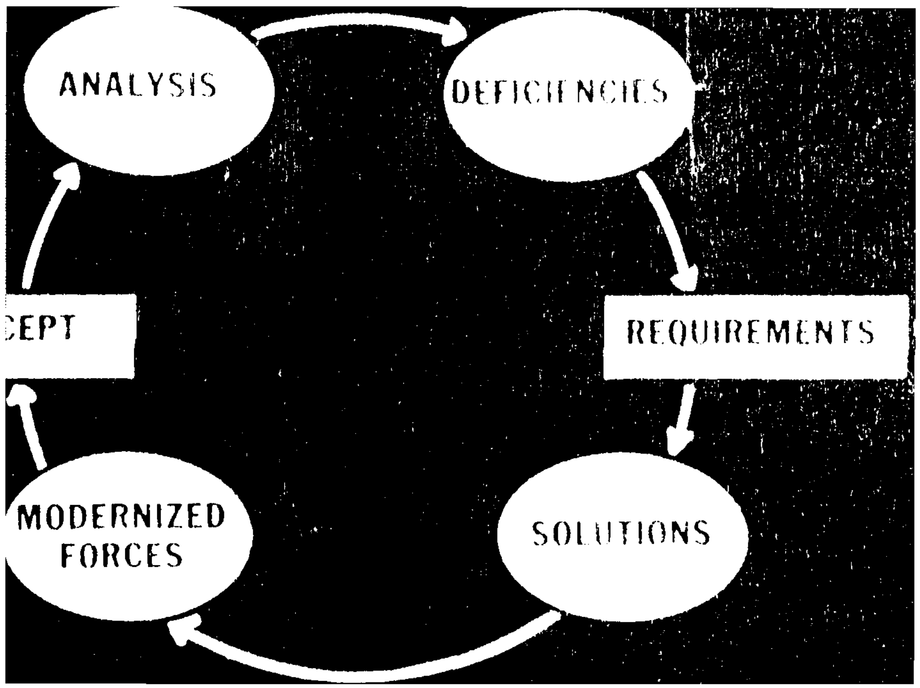
5
9

TERMINOLOGY

CONCEPT: GENERAL IDEA DESCRIBING HOW TO ACCOMPLISH CRITICAL BATTLEFIELD TASKS

DOCTRINE: HOW TO FIGHT AND HOW TO SUPPORT

UMBRELLA CONCEPT: A CONCEPT WHICH IS GENERIC IN NATURE AND ADDRESSES OPERATIONAL/ TACTICAL LEVELS OF WAR.


ANALYSIS
DEFICIENCIES
REQUIREMENTS
SOLUTIONS
MODERNIZED FORCES
CEPT

MATERIEL REQUIREMENTS

TECHNOLOGY FOCUS:

R&D → EQUIPMENT → DOCTRINE ORGANIZATION

CONCEPT FOCUS:

CONCEPTS → NEEDS → R&D → EQUIPMENT DOCTRINE ORGANIZATION

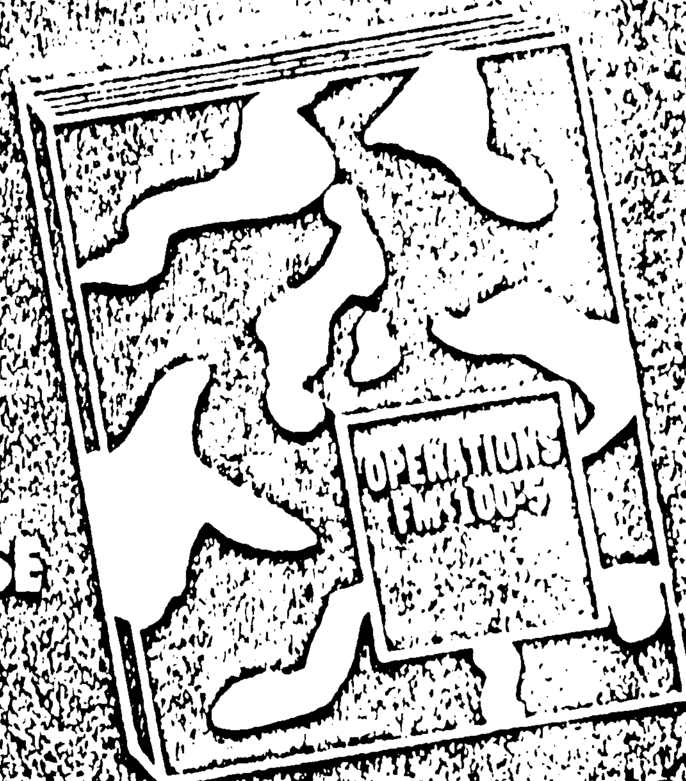
HEADQUARTERS TRADOC

AIRLAND BATTLE TODAY

LEVELS OF WAR

OPERATIONAL CONCEPTS

THE SPIRIT OF THE OFFENSE



HEADQUARTERS
TRADOC

1

DOCTRINE IS EVOLUTIONARY

ACTIVE DEFENSE
CENTRAL BATTLE
SECOND ECHELON
INTEGRATED BATTLEFIELD
EXTENDED BATTLEFIELD
AIRLAND BATTLE
AIRLAND BATTLE 2000
ARMY 21
FOCUS 21

HEADQUARTERS
TRADOC

ARMY 21

TRADOC AND AMC WARFIGHTING CONCEPT FOR THE EARLY 21ST CENTURY PROVIDES GUIDANCE FOR LONG RANGE PLANNING IN THE AREAS OF:

- DOCTRINE
- PERSONNEL REQUIREMENTS
- MATERIEL DEVELOPMENT
- ORGANIZATIONAL STRUCTURE
- TRAINING

FOLLOWS THE CONCEPT-BASED REQUIREMENTS SYSTEM

DYNAMIC CONCEPT - EVOLUTIONARY IMPLEMENTATION

HEADQUARTERS TRADOC

(13)

ARMY ENVIRONMENT 21ST CENTURY

- BALANCE OF POWER UNCERTAINTY
- POLITICAL AND ECONOMIC CLIMATE
- ENERGY AND STRATEGIC MATERIALS
- NEW TECHNOLOGY
- DEMOGRAPHIC VARIABLES
- CHANGING SOCIAL CLIMATE

HEADQUARTERS
TRADOC

62

87
3
103

IMPLICATIONS

- PREPARE TO FIGHT ANYWHERE
- WIN THE AIRLAND BATTLE
- WEAPON PARITY DEPENDENT UPON TECHNOLOGY
- AVOID DECISIVE ENGAGEMENT
- CRITICALITY OF INITIAL BATTLES
- STRATEGIC MOBILITY

HEADQUARTERS
TRADOC

BATTLEFIELD CHARACTERISTICS
21ST CENTURY

- BATTLE EXPANDED INTO THE AIRSPACE AND DEPTH OF ENEMY FORMATIONS
- INTENSIVE BATTLE AT THE DECISIVE POINT
- CHEMICAL/NUCLEAR/ELECTRONIC ENVIRONMENT
- LARGE QUANTITY OF SOPHISTICATED COMBAT SYSTEMS
- DIFFICULT COMMAND AND CONTROL
- NO SINGLE WEAPON SYSTEM WILL DOMINATE

HEADQUARTERS
TRADOC

63

91

109

(46)

ESSENCE ARMY 21

STYLE OF WAGING WAR IN WHICH AGILITY, DECEPTION, MANEUVER, AND FIREPOWER ARE USED TO FACE THE ENEMY WITH A SUCCESSION OF DANGEROUS AND UNEXPECTED SITUATIONS MORE RAPIDLY THAN HE CAN REACT TO THEM

HEADQUARTERS
TRADOC

66

93

111

SPIRIT OF THE CONCEPT

- SCAN
- SWARM
- STRIKE
- SCATTER

PRINCIPLES

INITIATIVE

DEPTH

AGILITY

[redacted]

SYNCHRONIZATION

HEADQUARTERS
TRADOC

INITIATIVE

SEIZE AND RETAIN INITIATIVE

OFFENSIVE SPIRIT

RISK TAKING TO EXPLOIT ENEMY VULNERABILITIES

"INDEPENDENT" ACTION BY SUBORDINATES

DECIDE AND ACT QUICKER THAN THE ENEMY

MANEUVER vs MOVEMENT OR MOBILITY

HEADQUARTERS
TRADOC

203

DEPTH

MOMENTUM IN THE ATTACK

TIME, DISTANCE, AND RESOURCES

ORIENT ON THE ENEMY

EXTENDED BATTLEFIELD

USE OF TERRAIN

LOGISTICAL READINESS

STATE OF MIND - RESOLVE, LEADERSHIP, COMPETENCE COHESIVENESS

CONTINUOUS OPERATIONS

ELASTICITY IN THE DEFENSE

HEADQUARTERS
TRADOC

AGILITY

OF THOUGHT AND ACTIONS BY ALL COMMANDERS

IMPLIES USE OF "INDIRECT APPROACH" AND MANEUVER

DEFEAT THE ENEMY'S WILL BY FRUSTRATING HIS INTENTIONS

KEEP THE ENEMY OFF BALANCE BY CONTINUALLY PRESENTING HIM WITH NEW SITUATIONS

MISSION SUFFICIENCY

SEE, ANALYZE, DECIDE AND ACT FASTER THAN THE ENEMY

HEADQUARTERS
TRADOC

DOC(3)850032

SYNCHRONIZATION

OF ACTION IN TIME AND SPACE

UNITY OF EFFORT - ACTIONS OF ALL ELEMENTS IN HARMONY WITH THE COMMANDER'S CONCEPT

COMBINED AND SUPPORTING ARMS

INTEGRATED STAFF ACTIONS

VIOLENT EXECUTION

HEADQUARTERS
TRADOC

206

W ENERGY SOURCES
ART WEAPONS/BRILLIANT MUNITION
EALTH
PROVED ARMOR
ACE DERIVED APPLICATIONS

Slide

FORCE CHARACTERISTICS

- SELF-SUFFICIENT ORGANIZATIONS
- HIGHLY MOBILE
- FIREPOWER INTENSIVE
- LESS MANPOWER RELIANT
- EXTREMELY AGILE
- RAPID STRATEGIC DEPLOYABILITY

Slide

FORCE CHARACTERISTICS

- EXTENSIVE USE OF ROBOTICS
- EW INCORPORATED IN ALL COMBAT FORCES
- REAL TIME INTELLIGENCE
- MOBILITY/SURVIVABILITY BUILT IN
- CROSS OBSTACLES IN STRIDE
- CAPABLE OF CONTINUOUS OPERATION

FORCE CHARACTERISTICS

- RECONSTITUTION CAPABILITY
- REDUNDANCY WHERE APPROPRIATE
- FAMILY OF VEHICLES
- INFORMATION PUSHED TO COMMANDERS
- ENERGY EFFICIENT
- APPLICATION OF POSITION LOCATING DEVICES

ARMY 21 FORCE STRUCTURE

- THEATER
- AIRLAND FORCE
- LAND BATTLE FORCE
- BATTLE TASK FORCE
- CLOSE COMBAT FORCE

HEADQUARTERS
TRADOC

Slide.

AIRLAND FORCE (ALF)

- NOTIONAL ORGANIZATION
- MULTISERVICE (ARMY, AIR AND NAVY COMPONENT)
- PERMANENTLY ORGANIZED
- ~~CAPABILITIES SIMILAR TO RAPID DEPLOYMENT JOINT TASK FORCE~~ ~~organized with a joint staff~~
- ORGANIZE WITH A JOINT STAFF

2.12

LAND BATTLE FORCE (LBF)

- ARMY COMPONENT OF ALF
- INTEGRATES, DIRECTS AND SUPPORTS THE LAND BATTLE
- DIRECT LINKS TO NATIONAL COMMAND, CONTROL AND INTELLIGENCE ASSETS
- OPERATIONAL AND SUPPORT CAPABILITIES SIMILAR TO CORPS AND EAC

BATTLE TASK FORCE (BTF)

- 0 PERMANENTLY ORGANIZED C^2 HEADQUARTERS OF THE CCF
- 0 DIRECTS TACTICAL OPERATIONS OF CCFs.
- 0 NO ORGANIC CS OR CSS
- 0 COMMAND AND CONTROL CAPABILITIES SIMILAR TO DIVISION HQ

CLOSE COMBAT FORCE (CCF)

- O BASIC COMBINED ARMS CLOSE COMBAT FORCE
- O CONDUCTS TACTICAL OPERATIONS
- O COMPOSED OF AN OPTIMAL MIX OF ORGANIC COMBAT, CS, AND CSS UNITS
- O SIMILAR IN SIZE TO A ~~SEPARATE BRIGADE~~ REGIMENT WITH FIREPOWER EQUAL TO A CURRENT DIVISION

SUPPORT CHARACTERISTICS

- CENTRALLY DIRECTED
- DECENTRALLY EXECUTED
- PREDICTABLE
- DISCIPLINED
- AUSTERE
- COMBAT ESSENTIALS

HEADQUARTERS
TRADOC

216

ARMY 21
SUPPORT FORCE STRUCTURE

- LAND BATTLE SUPPORT FORCE (LBSF)
- CLOSE COMBAT SUPPORT FORCE (CCSF)

HEADQUARTERS
TRADOC

LAND BATTLE SUPPORT FORCE (LSF)

- ORGANIC TO LAND BATTLE FORCE
- RESPONSIBLE FOR LOGISTICS PLANNING, MANAGEMENT, AND RECONSTITUTION OF THE CCF
- ORGANIZED TO PROVIDE COMPLETE LOGISTICS SUPPORT TO ARMY AND OTHER SERVICE COMPONENTS ASSIGNED TO ALF
- ESTABLISHES SUSTAINING BASE FOR CENTRALIZED MANAGEMENT AND CONTROL OF LOGISTICS OPERATIONS

HEADQUARTERS
TRADOC

CLOSE COMBAT SUPPORT FORCE (CCSF)

- ORGANIC TO CLOSE COMBAT FORCE
- PERFORMS SUPPLY, MAINTENANCE, TRANSPORTATION, PERSONNEL AND MEDICAL FUNCTIONS
- AUSTERITY OF BATTLEFIELD REQUIRES ONLY COMBAT ESSENTIAL SUPPORT BE PROVIDED
- TECHNOLOGICAL ADVANCEMENTS ENHANCE CCSF CAPABILITIES

HEADQUARTERS
TRADOC

SUPPLY AND SERVICES

- IMPROVED RATIONS
- MULTI-PURPOSE/ALTERNATE FUELS
- LIGHT-WEIGHT MUNITIONS
- ENHANCED AMMUNITION PACKAGING
- HYGENIC CLEANSERS

HEADQUARTERS
TRADOC

222

MAINTENANCE

- MODULAR REPLACEMENT
- REDUNDANT SYSTEMS
- BUILT-IN TEST EQUIPMENT
- AUTOMATED REPAIR CAPABILITY

HEADQUARTERS
TRADOC

150166b

TRANSPORTATION

- ON-BOARD NAVIGATION
- NBC AND BALLISTIC PROTECTION
- LESS TERRAIN RESTRICTIVE
- IMPROVED AERIAL DELIVERY SYSTEM
- SELF-LOAD CAPABILITY

HEADQUARTERS
TRADOC

SOLDIER/MACHINE INTERFACE

- HIGH TECHNOLOGY EQUIPMENT WILL DEMAND BETTER TRAINING
- FUTURE SOLDIERS MAY BE LESS MECHANICALLY INCLINED
- MODULAR MAINTENANCE AND REPAIR REQUIRED
- ADVANCED TECHNOLOGY MUST REDUCE REQUIRED SOLDIER SKILL LEVELS
- STRESS/HUMAN ENGINEERING

HEADQUARTERS
TRADOC

THE SOLDIER

CITIZEN SOLDIER

KEY TO COMBAT POWER

ROOTS IN A PLURALISTIC SOCIETY WHICH ESPOUSES:

- CULTURAL DIVERSITY
- DEMOCRATIC IDEALS
- INDIVIDUAL FREEDOMS
- SENSE OF FAIR PLAY

PRODUCT OF AN INFORMATION BASED/HIGH TECH SOCIETY

COMPUTER LITERACY IS A REALITY

WOMEN WILL MAKE UP A LARGER SEGMENT OF THE TOTAL ARMY

HEADQUARTERS
TRADOC

DO. .065

ARMY 21

PRESENTS THE TRADOC AND AMC WARFIGHTING CONCEPT FOR THE FUTURE

- TIME FRAME 2000 THRU 2025
- LOW TO MID/HIGH INTENSITY CONFLICT

A DYNAMIC CONCEPT

- CONTINUE TO REFINE
- TENETS VALIDATED THROUGH WARGAMING

STRONGLY DEPENDENT ON TECHNOLOGY

- GENERAL GUIDANCE FOR R&D STRATEGY
- COMPLEMENTS THE CONCEPT BASED REQUIREMENTS SYSTEMS

STATUS

- CONCEPT PREPARED FOR PUBLICATION
- DISSEMINATION EXPECTED THIS SUMMER

HEADQUARTERS
TRADOC

SUMMARY

- THE US ARMY IS IN TRANSITION
- KEY IS CONCEPT BASED REQUIREMENTS SYSTEM
- DOCTRINE IS DYNAMIC
- AIRLAND BATTLE IS THE CURRENT DOCTRINE
- ARMY 21 — A CONCEPT FOR THE FUTURE

HEADQUARTERS
TRADOC

DOC(3)850032

DR. ROBERT FINKELSTEIN

<u>Combat Robotics of the Future</u>

Combat Robotics— Now and the Future

— Robert Finkelstein

What Is a Robot?

The Word "Robot":

- Originated by Czechoslovakian Dramatist Karel Capek in 1917 Short Story "Opilec"
  - Derived from "Robota", Czech for "Work", "Forced Labor", or "Servitude"
  - Gained Major Exposure in Capek's 1920's Play, "R.U.R." (Rossum's Universal Robots)

Some Simple Definitions

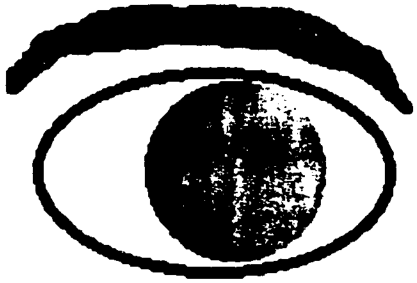
- Cybernetic Systems
  - Systems Perceived to Be Goal-Directed
- Artificially Intelligent Systems
  - Machines (Computers) Perceived to Be Intelligent
- Unmanned Vehicle Systems
  - Vehicles Which Behave as If a Person Were on Board
- Robotic Systems
  - Machines Able to Sense and Perceive Their Environment, Make Decisions Based on Their Perceptions and Prior Knowledge, and Take Physical Action

Japanese Definition of Robot

A mechanical system which has flexible motion functions of living organisms or combines such motion functions with intelligent functions (such as judgment, recognition, adaptation, or learning), and which acts in response to the human will.

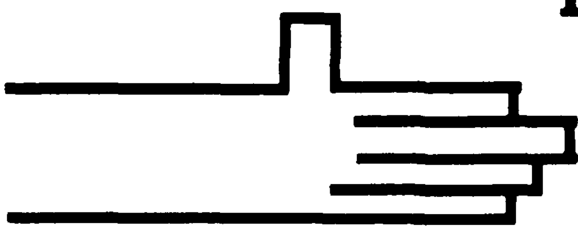
— The Japanese define several categories of robots.

ROBOT

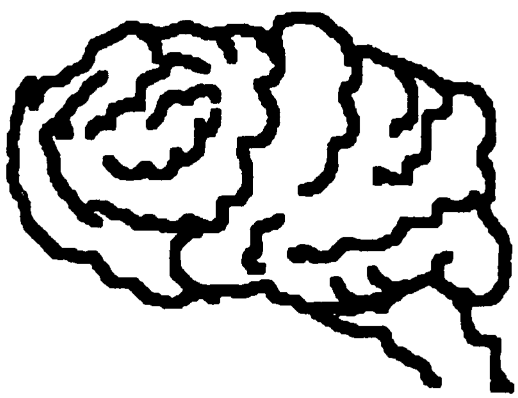


SENSORS

EFFECTORS



PROCESSOR



What Is a Robot?

- A robot is a non-living system having sensors, processors, and effectors able to respond appropriately to its environment.
  - — Behavior should appear, to a human observer, complex, purposeful, adaptive, and surprising.
  - — Need not resemble human beings or any other living creature.

Robot Relatives

- Automatons
  - From Greek "Automatos", "Acting of Itself"
  - Clockwork Type Devices Operating under Previously Supplied Programming (or Gear Patterns)
- Androids
  - From Greek "Andros", "of Man", and "Eidos", "Form", That Is, "Form of Man"
  - A Robot That Resembles a Person
- Cyborgs, Mandroids, Mechanoids, Robotoids, Parabots. . .

The Three Laws of Robotics

(Originated by Author Isaac Asimov in 1950 in the Book *"I Robot"*.)

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

The Three Laws of Robotics

(Continued)

2. A robot must obey the orders given it by human beings except where such orders would conflict with the first law.
3. A robot must protect its own existence as long as such protection does not conflict with the first or second law.

Why Does the U.S. Military Need Robotics?

- High Combat Attrition
- Manpower Problems
- High Materiel Costs
- High Personnel Costs
- Deterioration of Defense Industrial Base

Why Does the U.S. Military Need Robotic Weapons?

- Smaller
- Less Complicated
- More Sophisticated
- Cheaper
- Expendable
- More Survivable
- Fewer, Lower-Skilled Personnel
- Technological Advantage

Example: Manned Versus Robotic Aircraft Attrition Costs

Assume: 1,000 Attack Aircraft, 3 Sorties per Day, $20,000,000 per Aircraft

With an attrition rate per sortie of 3%, about 87 of the aircraft would be lost the first day, at a cost of $1,800,000,000.

With attrition at 20%, about 488 aircraft would be lost at a cost of $9,800,000,000.

This represents 45,000 to 245,000 mini robotic aircraft at $40,000 each.

What's Different?

Robotic systems place man at a greater distance from the contact point—standoff distance increased.

$$\underset{\text{(Heuristic)}}{\text{Manned}} \longrightarrow \underbrace{\text{Man} + \underset{\text{(Algorithmic)}}{\text{Weapon}}}_{\text{(Heuristic)}} \longrightarrow \underset{\text{(Heuristic)}}{\text{Weapon}}$$

COMBAT ROBOTICS APPLICATIONS

Space

*Planetary Exploration
*Earth Satellites
*SDI ("Star Wars")

Air

*Reconnaissance
*Surveillance
*Electronic Warfare
*Electronic Countermeasures
*Kamikaze
*Weapons Delivery
*Communications Relay

COMBAT ROBOTICS APPLICATIONS

Sea

*Search and Identification
*Retrieval of Personnel and
Materiel
*Repair
*Anti-Submarine Warfare
*Anti-Mine Systems

Land

*Reconnaissance & Surveillance
*Ammunition Handling
*Autonomous Weapons
*Nuclear, Biological, Chemical
Decontamination
*Sentries
*Countermine Robot
*Explosive Ordnance Disposal
*Rapid Excavation
*Deception
*Countermobility/Barriers

ROBOTIC VEHICLE PROGRAMS

DARPA

- Autonomous Land Vehicle
- AI Subsystems

ARMY

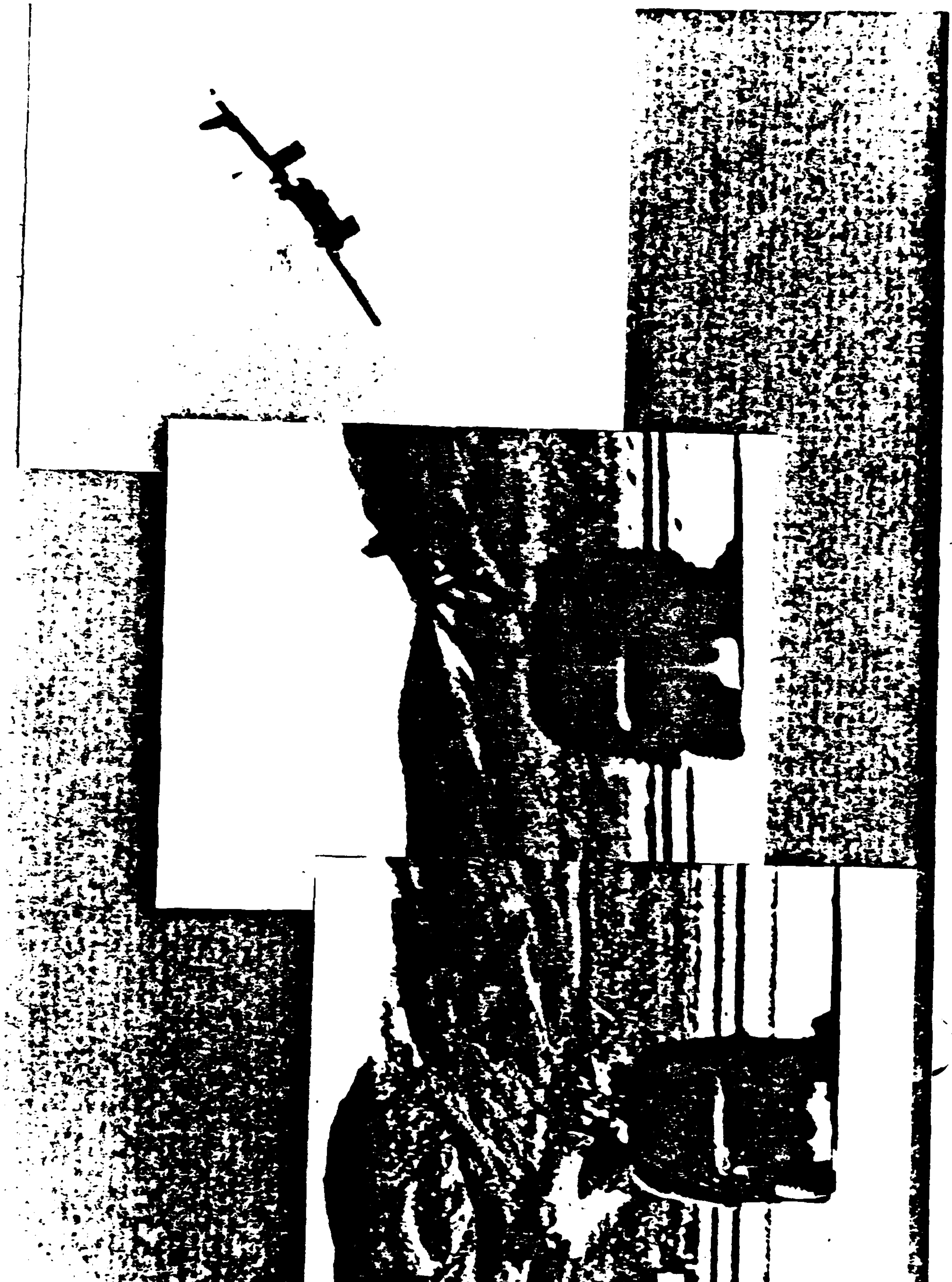
- Teleoperator/Recon Vehicle
- AQUILA RPV

NAVY/MARINES

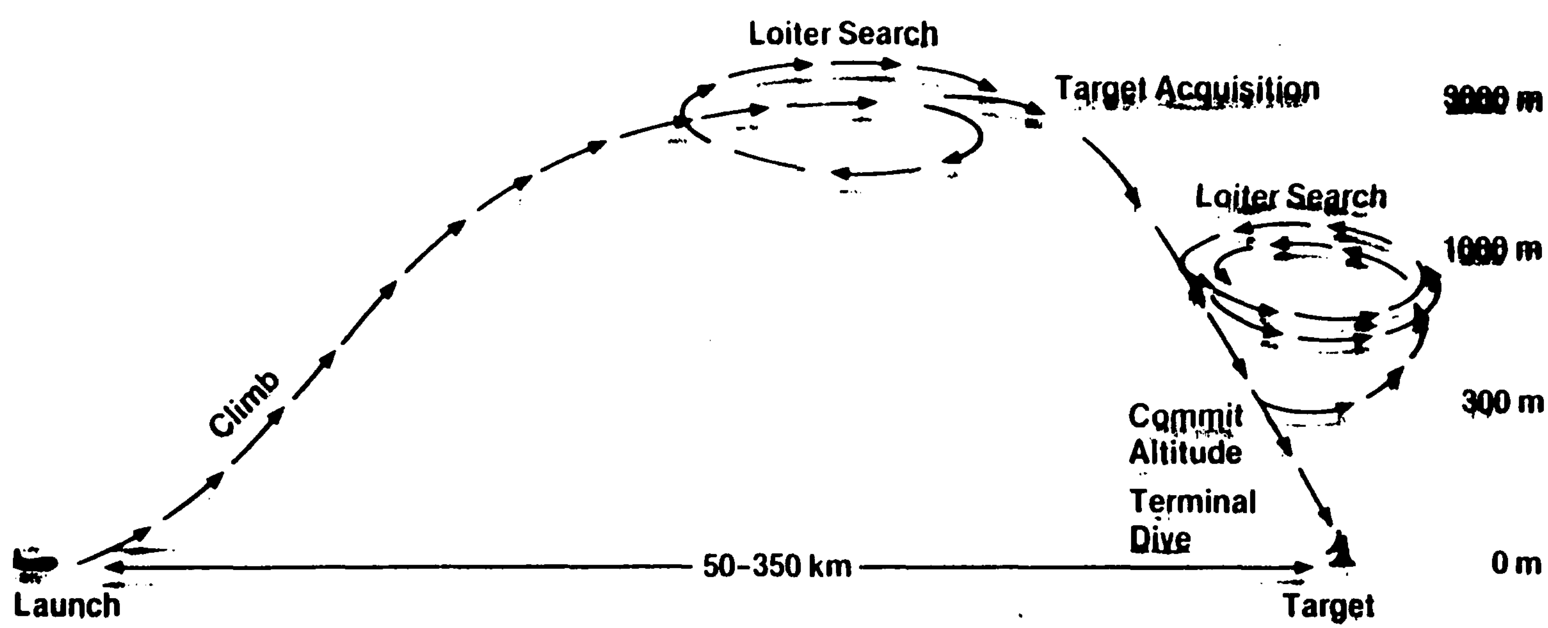
- Unmanned Submarine
- RPVs
- Cruise Missiles
- Anthropomorphic Teleoperator
- Ground Surveillance Vehicle
- Target Drones

AIR FORCE

- Cruise Missiles
- Mini-Attack Drones
- Target Drones



Nominal Drone Mission Profile



Possible Robotic Evolution

Year	System Type	Example
1984-1986	Teleoperators	RPV, Tow, Recon Sentry
1986-1990	Unintelligent Robots	Munition Handlers, Drones, Cruise MSLS
1990-2000	Semi-Intelligent Robots	Recon, Drones, Manufacturing
2000-2010	Intelligent Robots	Tanks, Air Defense, Recon, Artillery, Fighter Aircraft

Defense Advanced Projects Research Agency (DARPA) Strategic Computing Program

Autonomous Land Vehicle Project

- Expert Systems
- Vision
- Voice Understanding

Autonomous Land Vehicle Goals

1985: Road Following Demonstration

- Pre-Set 20 km Route
- 10 km/Hr. Forward Motion

1986: Obstacle Avoidance Demonstration

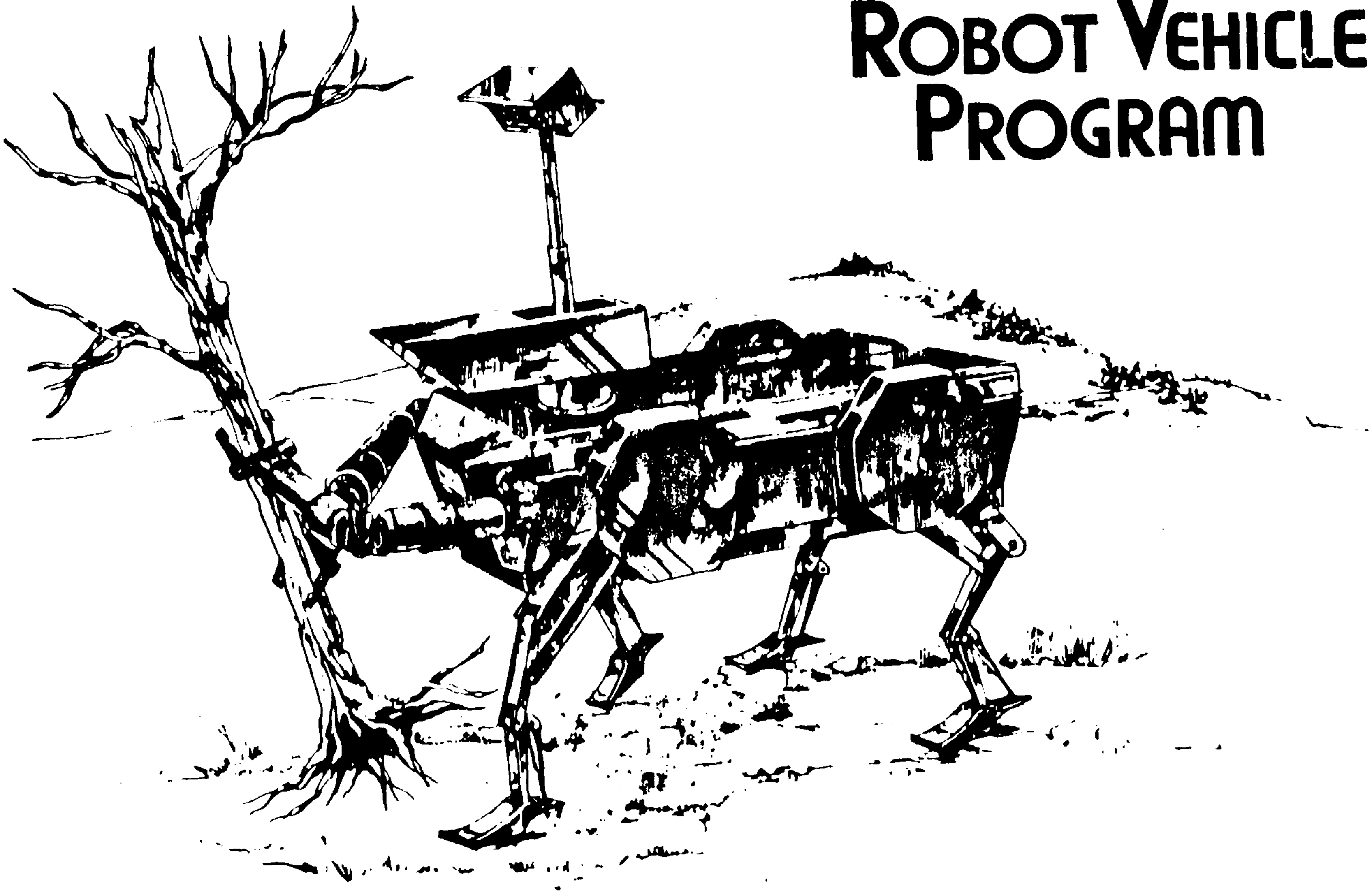
- Over 20 km Course
- 20 km/Hr.
- Polyhedral Objects Less Than 100 m Apart

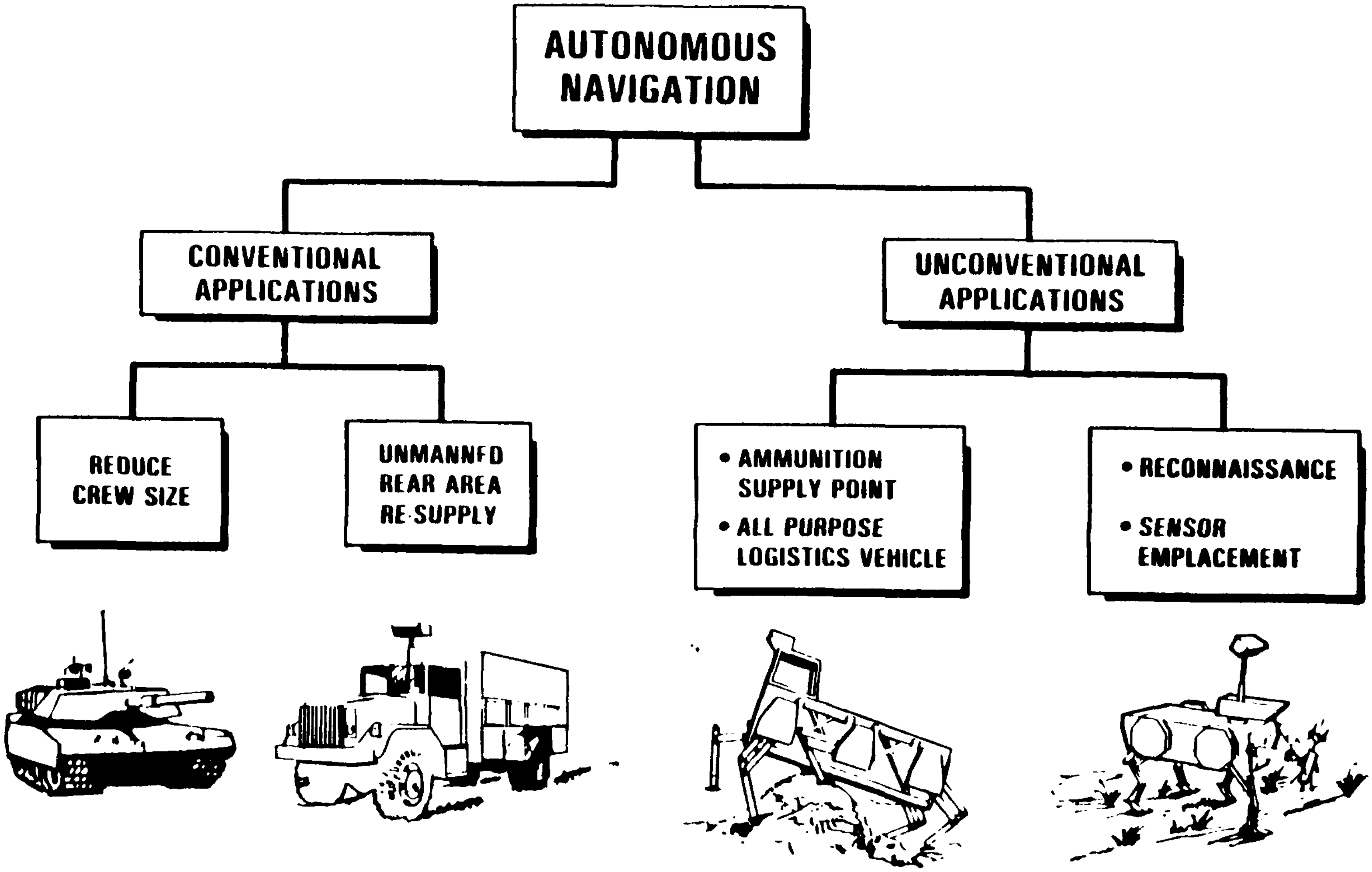
Autonomous Land Vehicle Goals
(Continued)

1990: Mixed Road and Open Terrain Demonstration

- Up to 20 km Traverse over Desert Terrain with Isolated Objects
- Up to 50 km on Paved or Unpaved Roads
- 30 km/Hr.
- Route Planning
- Operate among Other Moving Vehicles

Autonomous Robot Vehicle Program

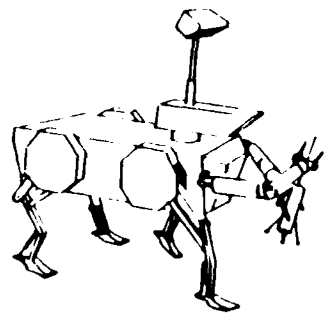


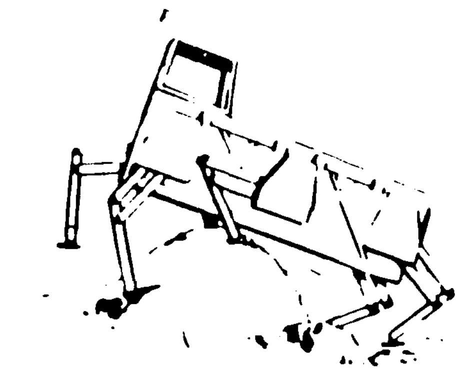


ADVANTAGES:

- Immunity to stress
- No fatique
- Optimized performance

Autonomous Land Vehicles



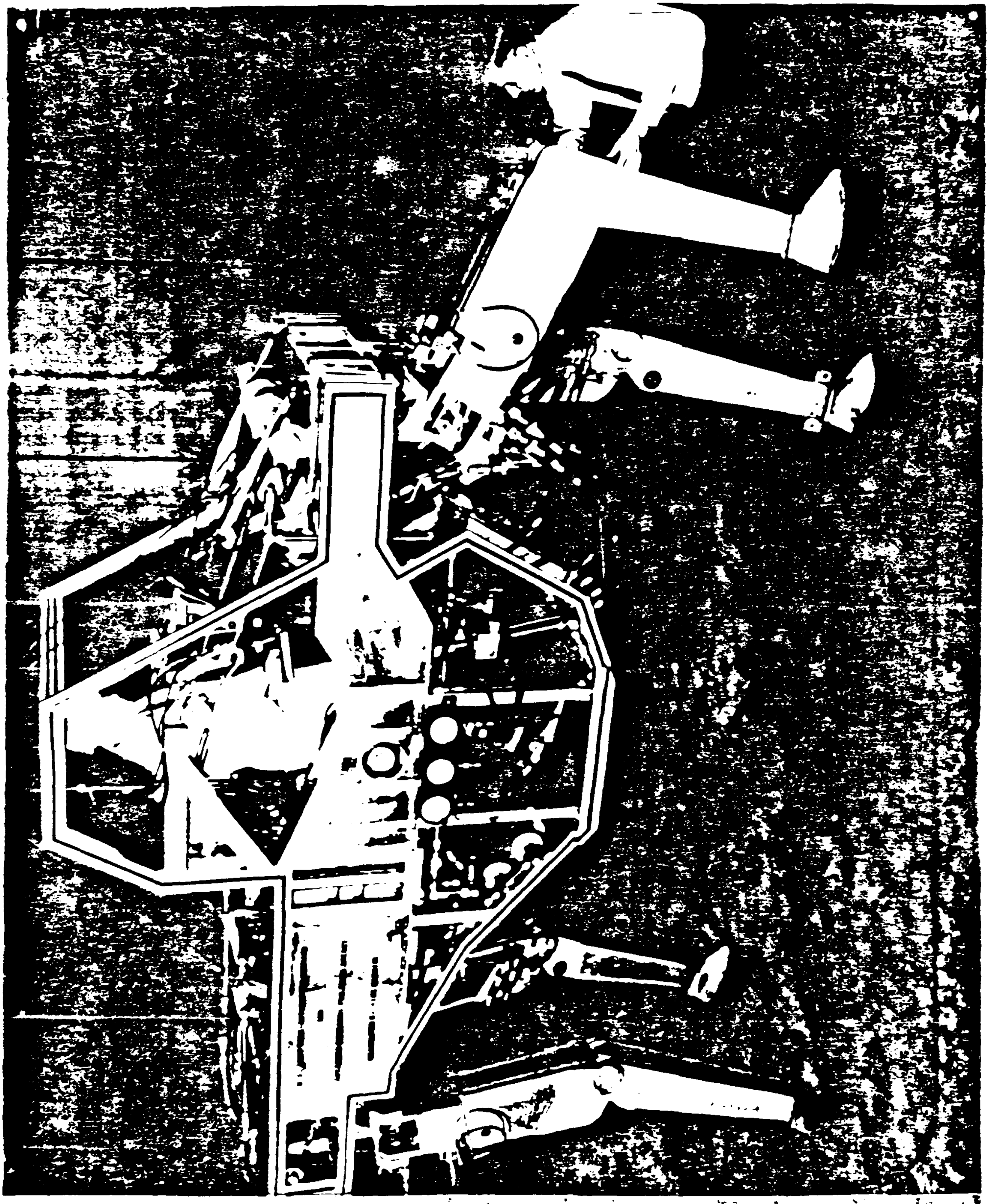


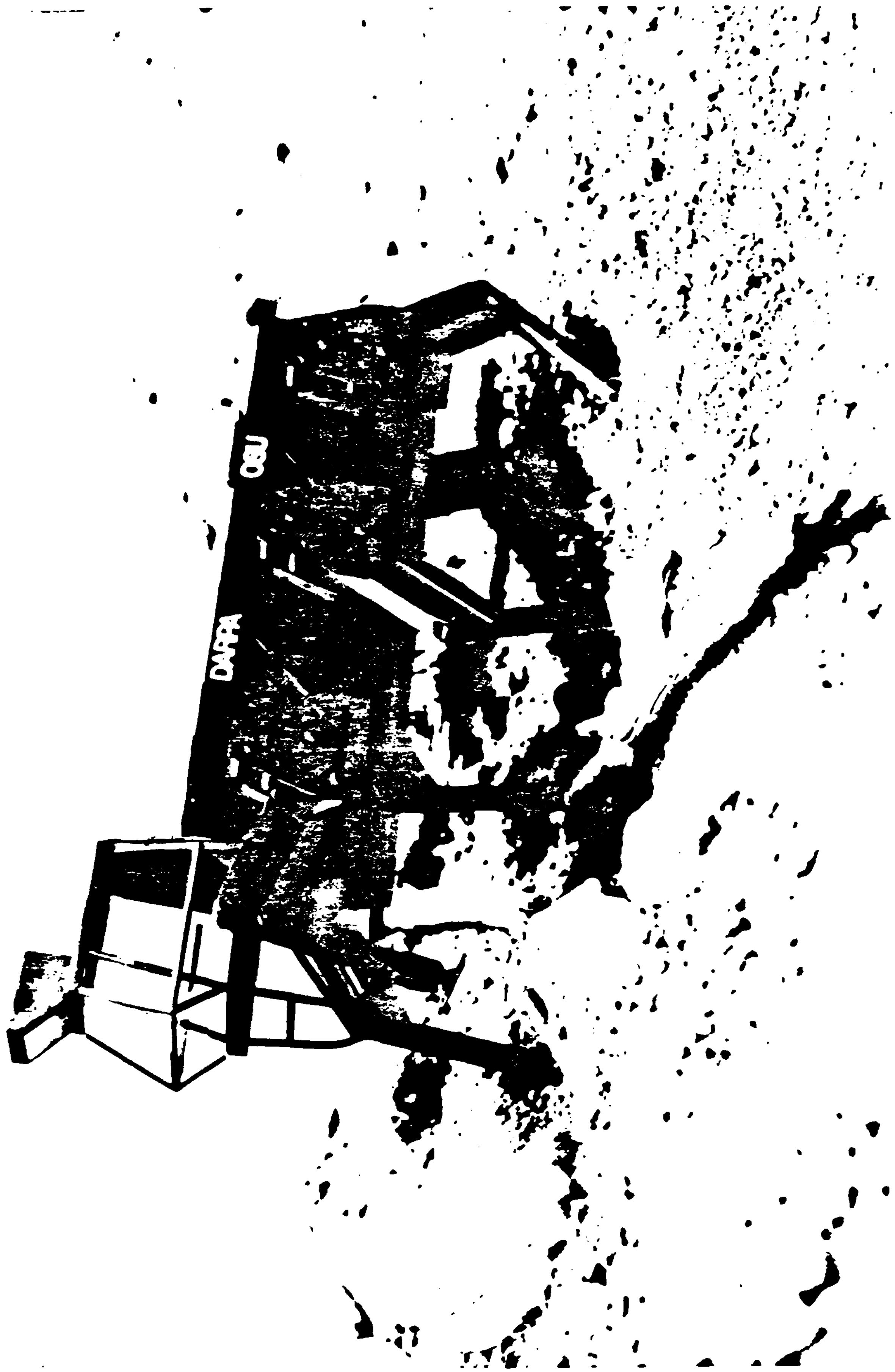
SOME APPLICABLE MILITARY MISSIONS

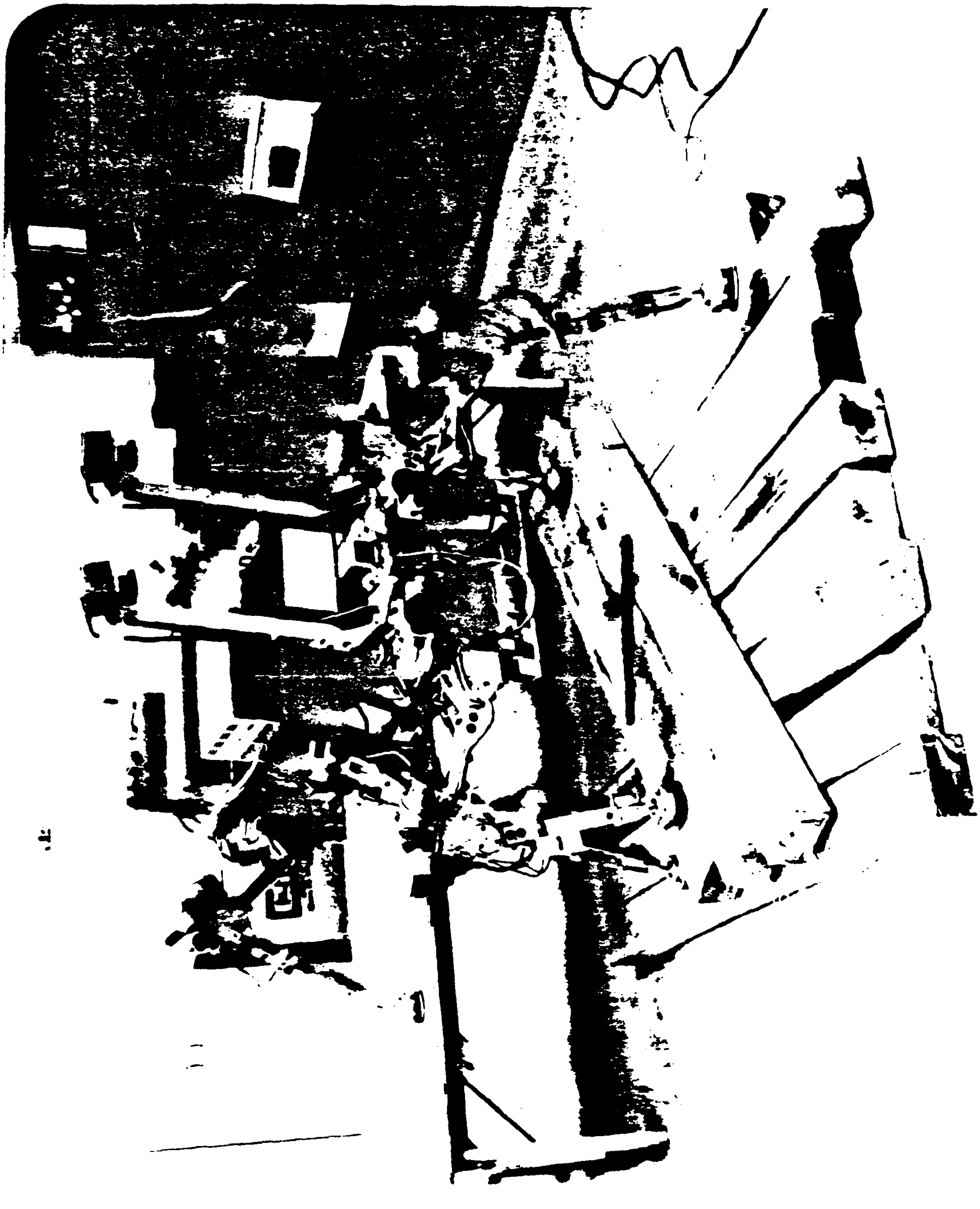
- Reconnaissance
- Sensor emplacement
- Target designation
- Mine clearing
- Weapons platform
- Rescue
- Contaminated environments
- Smart logistics transporter
- Communications relay

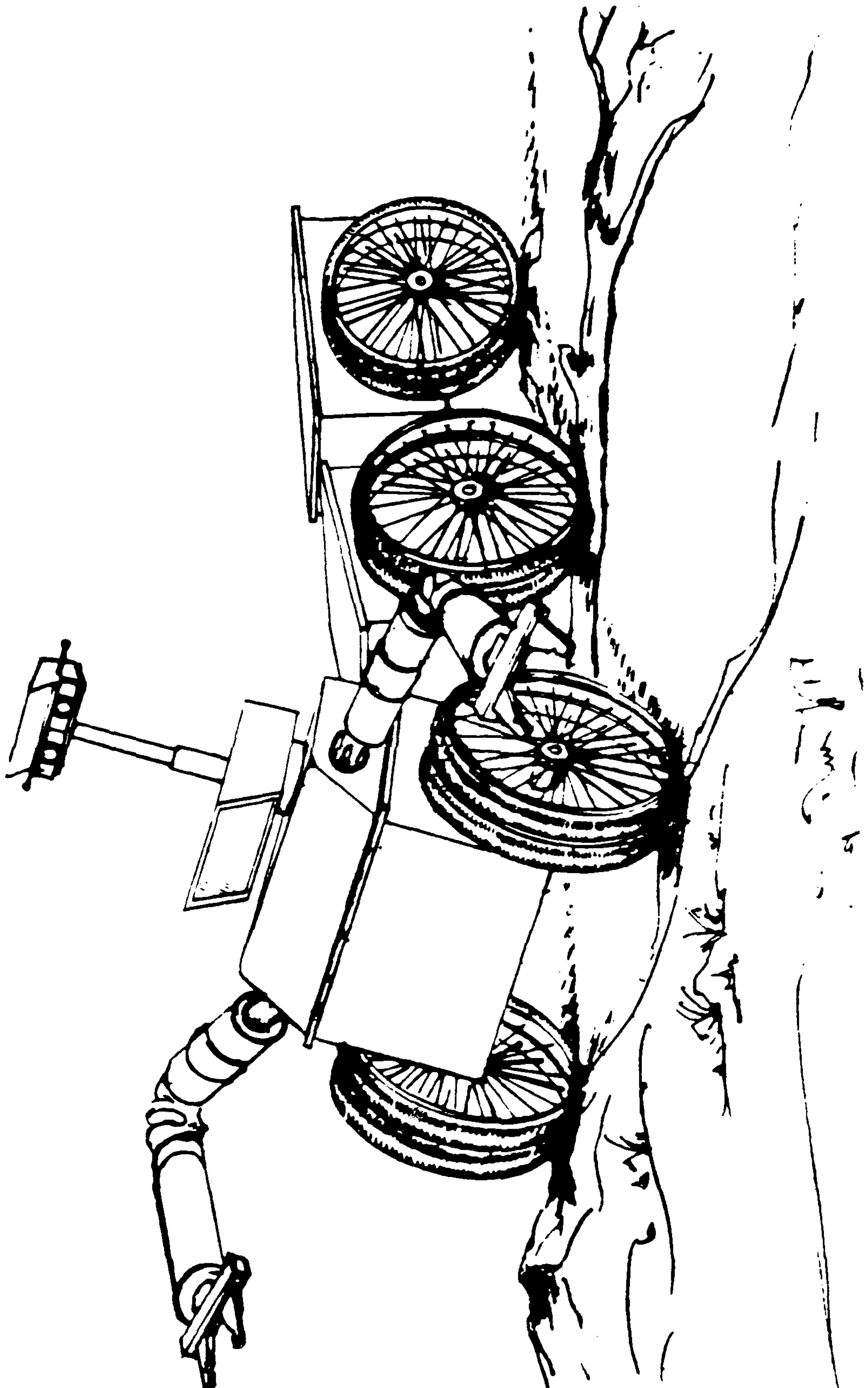
FEATURES

- Cross country capability
- Digital terrain data base
- Multiple on-board imaging sensors
  - Scene analyzer and interpreter
- Navigation based on expert systems
  - Planner
  - Map maker
  - Pilot
- Real time update by sensors
  - Local obstacle avoidance
  - Supplement terrain data




OSU
DARPA





U.S. Army Robotic Vehicle Demonstration System

- Reconnaissance and Surveillance
- Nuclear, Biological, and Chemical Detection and Decontamination
- Weapons Systems
- For Air-Land Battle 2000
- Evolve from Teleoperator to Robot

Telepresence Module

- On M-113 Armored Personnel Carrier
- Stereo, Color Vision
- Stereo Audio
- Automatic Route Planning
  - Digital Terrain Maps
    - 60 Megabyte Disks
    - 1 Megabyte Operations per Sec

U.S. Army Robotic Ranger Program

- Platform about 0.2 Cubic Meters
- Teleoperate to Distances of 45 km by Fiber Optic Link
- Carry Warhead or Mine under Armored Vehicle
- Less Than $25,000
- Mobile over 50% European Terrain

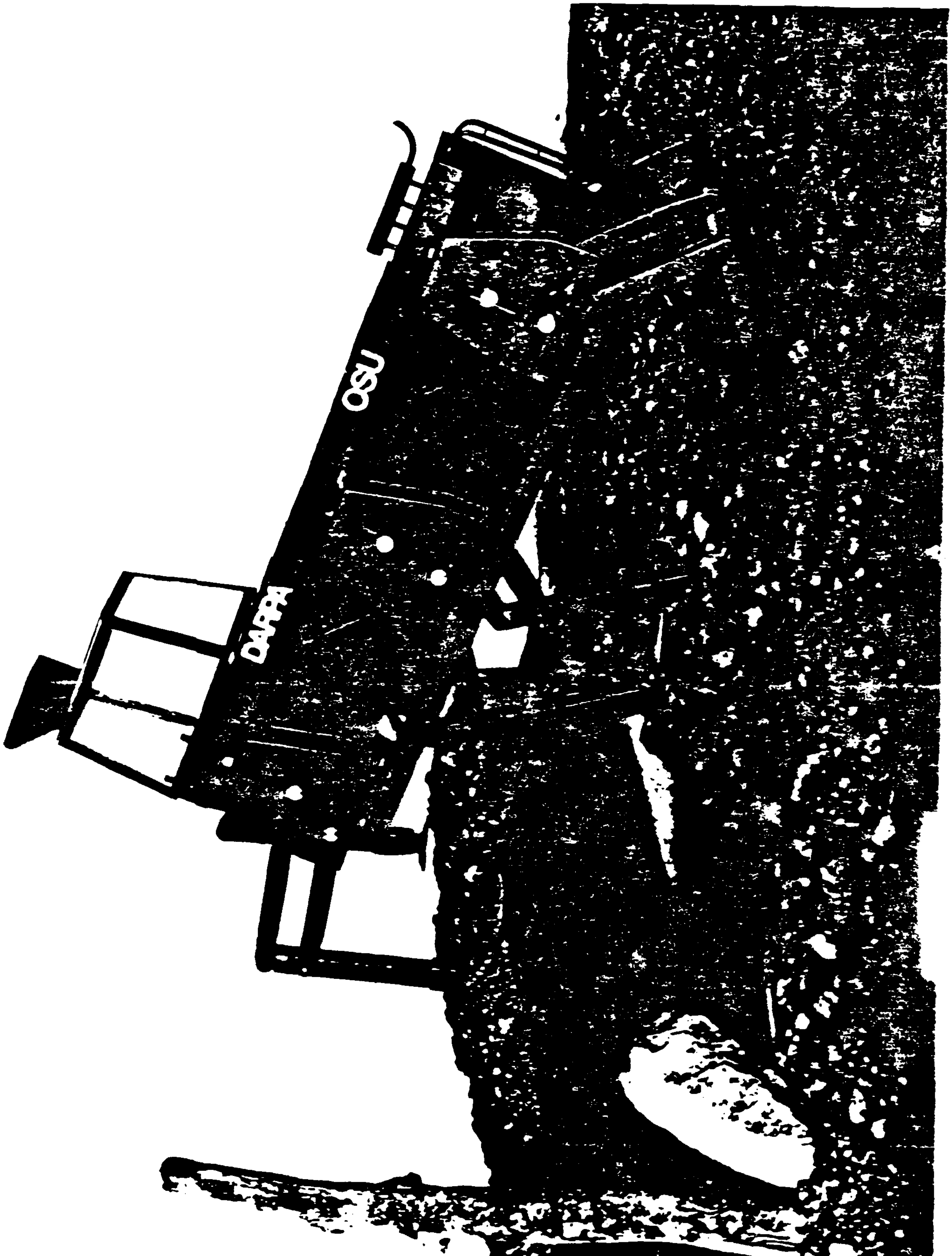
Adaptable to Other Missions

- Reconnaissance
- Laser Designation
- Deception
- CBR Detection
- Small Weapons Platform
- Remote Wire Laying
- Demolitions
- Smoke/Chemical Dispersion

U.S. Army Robotic Autonomous Mobile Mine (RAMM)

To Interdict Second Echelon Forces or Use in FLOT (Forward Line of Own Troops) Zone

- Launched 10-15 km Behind FLOT to Destination (Up to 45 km Range)
- Soft "Crash" Landing
- Static Acquisition Mode (4-5 Days)
- Target Acquisition
- High-Speed Ground Skimming to Armored Target (Up to 1 km)
- Detonate 10 kg Warhead at Target Bottom


DARPA
OSU

U.S. Navy Concept Study—Autonomous Underwater Vehicles

Applications

- Under-Ice Reconnaissance
- Weapon or Sensor Implantment
- AWS Training

1000 km Range (or More)

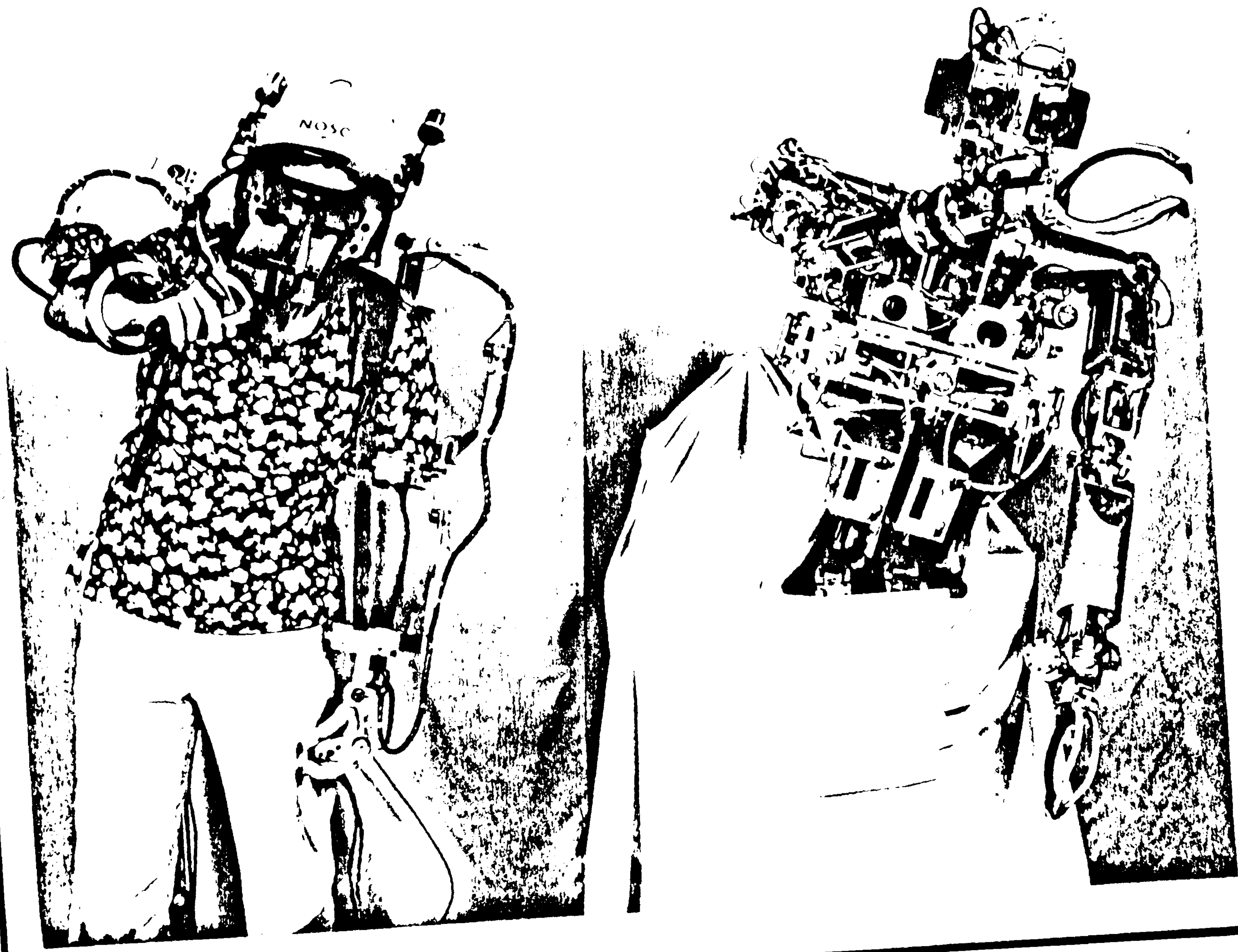
10 to 50 Metric Tons Payload

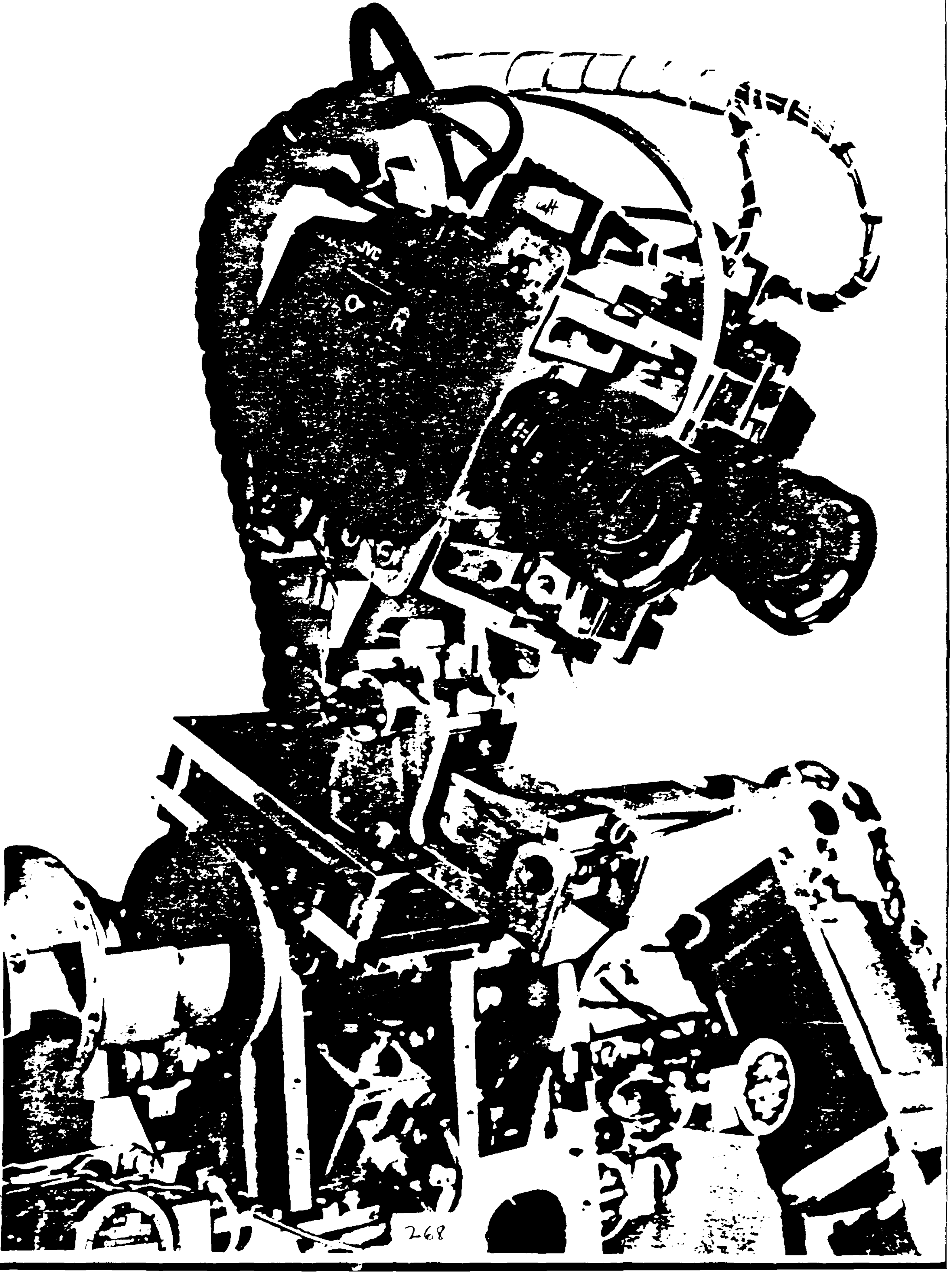
Pertinent Technology

- High Energy Density, Closed Cycle Power Plants
- Compact, Highly Reliable Navigation
- LSI and VLSI Digital Technology
- Knowledge-Based Systems

U.S. Marine Corps

- Teleoperated Anthropomorphic System
- Ground Surveillance Robot Vehicle


NOSC


JVC

ODEX I

Height: 1-2 m (Variable
Weight: 170 kg
Width: 53 cm (Narrow Configuration)
Maximum Articulator Spacing: 3 m
Maximum Load: 820 kg (Slow Walk)
Maximum Load: 450 kg (Fast Walk)
Fast Walk Speed: 5 km/Hr.
Climbing Step Height: 84 cm

Tripod Gate

Excellent Strength-to-Weight Ratio and Agility

ODEX I

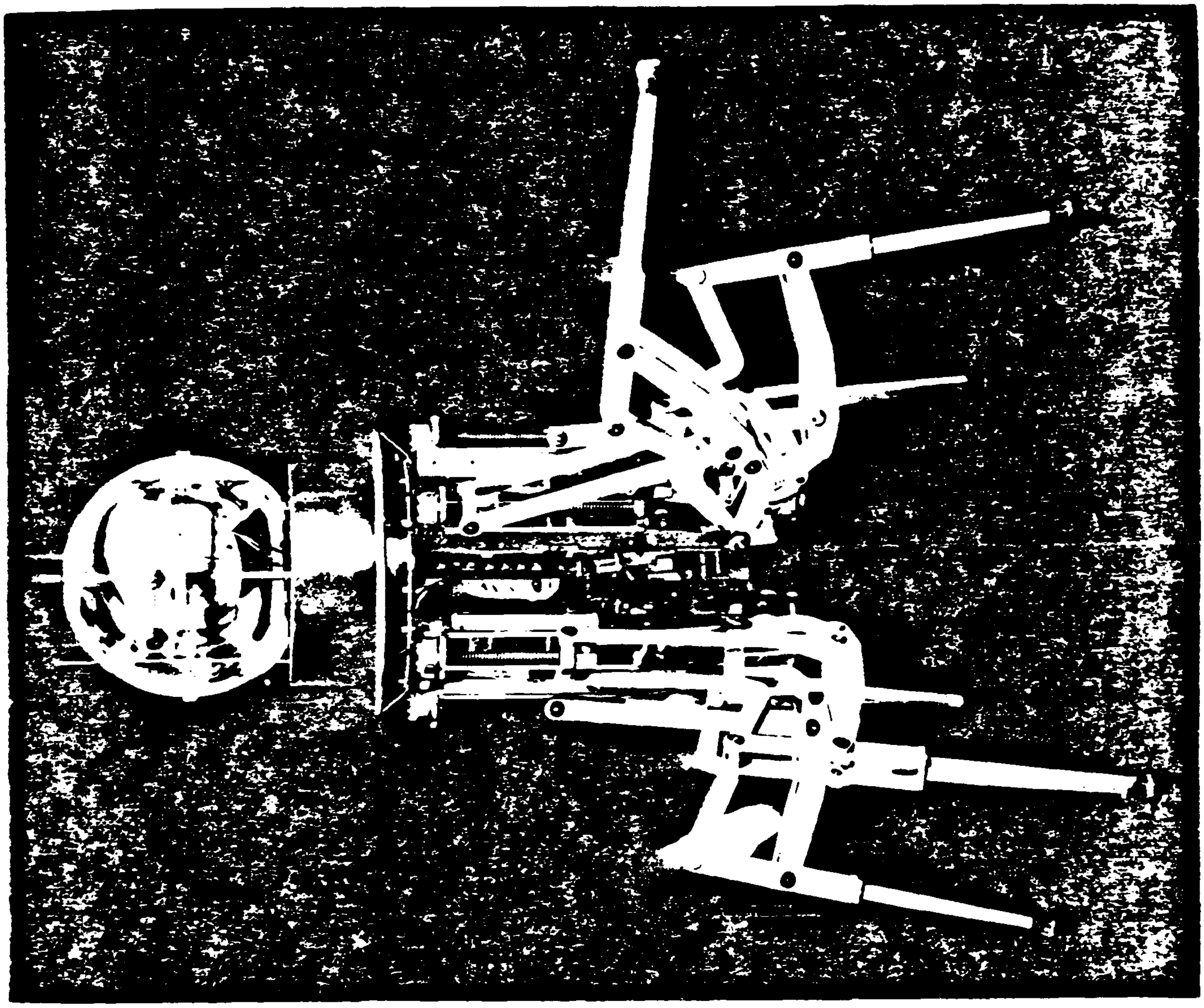
(Continued)

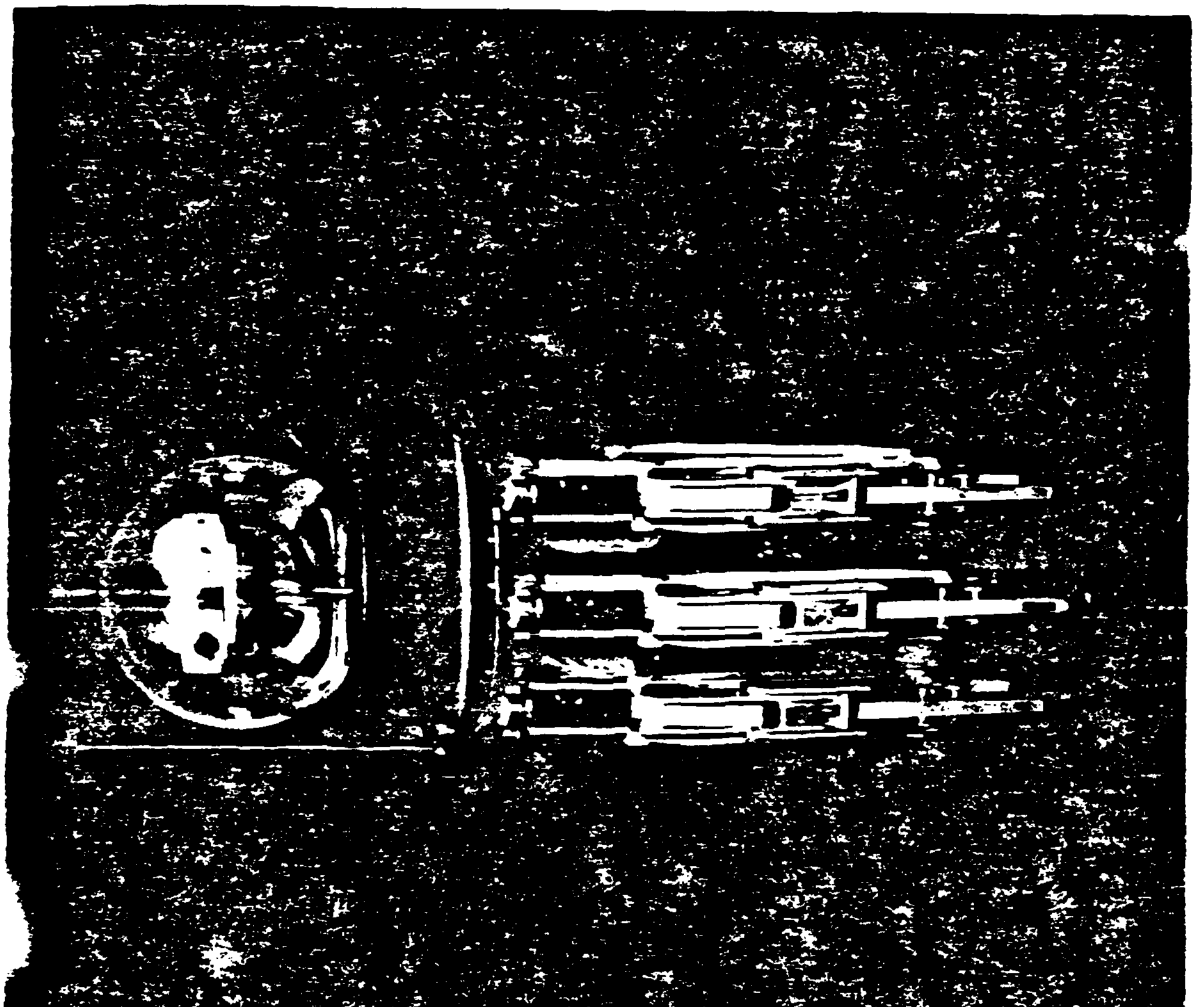
3 Motors per Articulator (18 Motors Total)
24 V, 25 Amp-Hour Aircraft Battery
450 Watts, Recharge in One Hour of Normal Walking

6 Level-1 Computers (1 per Articulator)
1 Level-2 Computer

Joystick Controls via Radio Link

Future: Vision, Sonar, Autonomy, Route Planning, Tactile Sensors for Articulators





PROWLER Sentry

First Generation

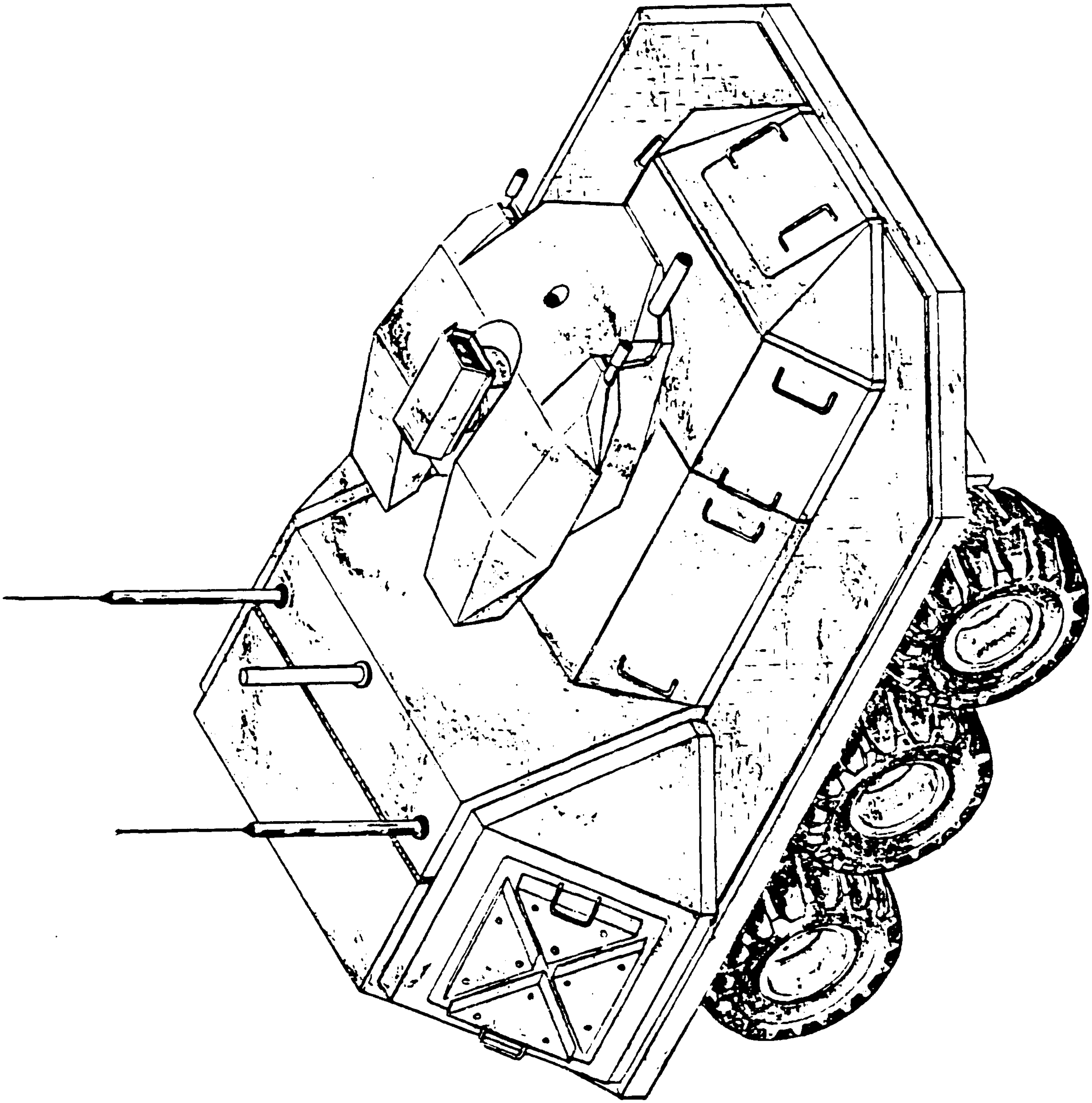
- Maze Following
- Weight: 600 kg
- 4 on-Board, 8-bit Microprocessors
- Telescoping (7 m) Pod for CCTC Sensors
- Sonic Ranging
- Driving and Coordinating Software
- Wheel Encoders
- Electrically Powered

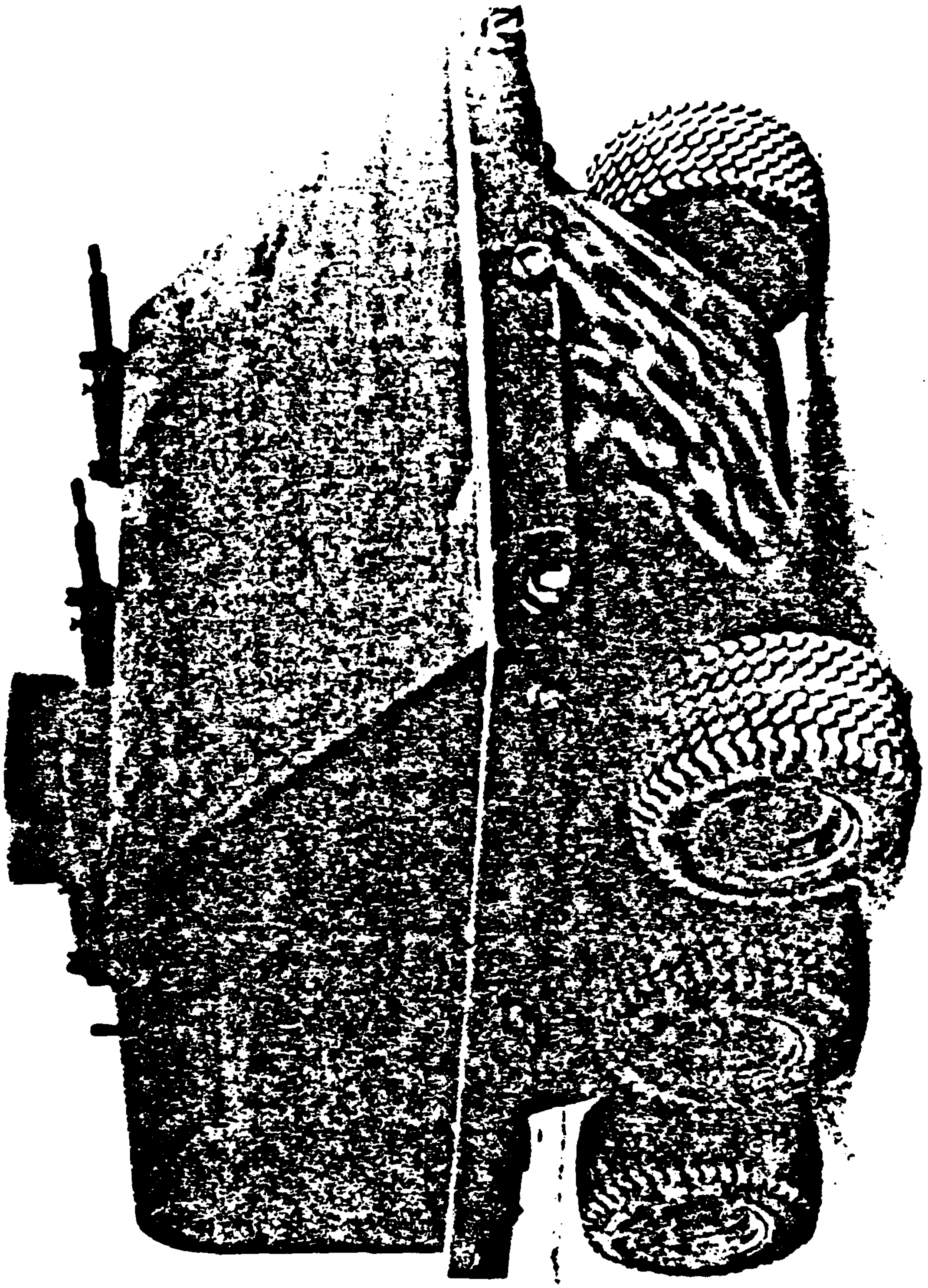
PROWLER Sentry

(Continued)

Second Generation (Available April 1985)

- Autonomously Patrol Perimeter of Secure Site Delineated by Road or Fence
- Weight: 1,800 kg
- Diesel Powered
- 6 on-Board, 32-Bit 68000-Family Microprocessors—Emulating LISP Machine
- CCD and Laser Vision, Color TV
- Gyro Attitude Sensor
- Microwave Video and Optional Control Link to Manned Station
- Manned Station: Color Graphics Monitor with Video and Computer Enhanced Map
- Payload: 1,000 kg, Weapons or Sensors





DoD Policy

- No Comprehensive, Coherent Policy
- Policy Is Forming

"...Advancement of the state-of-the-art and application of robotics and related technology is important to the future of the nation and to DoD's *ability to provide for national defense needs.*"

— Edith W. Martin
Deputy Undersecretary
of Defense

DoD Policy

Robotics is one of the most important development areas for the U.S. Marine Corps.

— Brigadier General Joseph E. Hopkins
Director of the Quantico Development Center

Soviet Interest

"At our institute, projects are underway to teach robots languages and a 'ratio al' approach to different problems.

"In certain fields of knowledge, we are able to create algorithms by which a machine will learn more rapidly than even a very capable human.

"I will not conceal the fact that our goal is to create a 'thinking' robot by the year 2000."

— Academician V. Glushkov
Director, Institute of
Cybernetics, Kiev

U.S. Government Robotics R&D Spending

	FY 82	FY 83
DoD	$27 Million	$44 Million
Other Agencies • NSF • NASA • NBS	$9 Million	$10 Million

DoD in FY 90: $1 Billion?

Effects

- Tactical
- Strategic
- Organizational
- Political
- Cultural

First Order Effects

- More Accurate Weapons
- More Flexible Weapons
- Faster, Cheaper, More Reliable Weapons Manufacture
- Improved C^3I
- Replacement of Humans in Hazardous Tasks

Second Order Effects

- Reduction of Rear Echelon Personnel
- Changes in Organization, Composition, and Structure of Forces
  - Smaller Units
  - Rapid Deployment
  - Mixed Forces
  - Multi-Media Weapons
- Changes in Tactics
  - Increased Dynamics
  - Increased Coordination
  - Information as Force Multiplier
  - Offensive Defense
  - Nonnuclear Deterrent

Second Order Effects
(Continued)

- Shifts in Personnel Skill Levels
  - New Skills
  - Lower Skills
- Changes in Training Programs
  - Retraining
  - Courses
  - Field Exercises Against Machines
- Changes in Recruiting Policies
  - Numbers
  - Quality
  - Terms

Third Order Effects

- **Changes in Doctrine and Strategy**
  - Elimination of Mutual Assured Destruction (MAD)
  - Nonnuclear Deterrent
  - Blurring Distinction Between Tactical and Strategic War
  - Parity of Defense with Offense
- **Changes in Warfare Philosophy and Modes**
  - Increased Willingness to Go to War
  - Decreased Willingness to Go to War
  - Potlatch Warfare
  - Less Developed Countries More Vulnerable to Super Powers

Third Order Effects
(Continued)

- Moral and Legal Repercussions
  - — If War Easier
  - — Use of Intelligent Machines
- Large Reductions in Number of Personnel under Arms
  - — More Power and Belligerence
  - — Less Power and Belligerence
- Peace
  - — More
  - — Less
  - — No Change

Personnel Implications

Year	Activity	Personnel			Robots
		Qnty	Qlty	Cat	Qnty & Qlty
1985	Materiel	+	0	+	+
	Operations	0	0	+	0
	Support	0	0	0	0
1995	Materiel	0	+	+ +	+ +
	Operations	0	−	+ +	+
	Support	−	+	0	0
2005	Materiel	− −	+ +	+ +	+ +
	Operations	− −	+	− −	+ +
	Support	− −	+ +	0	+

Robotic Research Issues

Mechanical Systems

- More Flexible, Stronger, Coordinated Arms
- More Dexterous End Effectors (Hands and Fingers) with Tactile Sensors
- Better Locomotion (Wheels, Tracks, Legs, Propellers)

Processors

- Faster Computers, More Memory
- Better Software
  - Expert Systems
  - Natural Language
  - Vision
  - Computational Ability

Robotic Research Issues
(Continued)

Sensors

- Vision
- Infrared (Active and Passive)
- Acoustic (Active and Passive)
- Millimeter Wave (Active and Passive)
- Tactile
- Smell

Control Systems

- On Board
  - First and Second Order Cybernetics
- Man/Machine Interface
  - Robot Language
  - Voice Synthesis
  - Voice Recognition/Understanding
  - Displays
  - Teaching Systems

MILITARY ROBOTICS: RESOURCE MANAGEMENT ISSUES

* Costs
  - Research & Development
  - Life Cycle
    - TECHNOLOGY
    - SYSTEMS
    - PERSONNEL
    - ORGANIZATIONAL/ADMINISTRATIVE

* Effectiveness
  - Measures of Effectiveness
  - Test & Evaluation

MILITARY ROBOTICS: RESOURCE MANAGEMENT ISSUES

* **Personnel**
  - Categories/Skills
  - Quantity
  - Intellectual Abilities
  - Physical Abilities
  - Psychological Impacts

* **Systems**
  - Organizational & Operational
    - ARCHITECTURE/PROCEDURES
    - JOINT SERVICE DEVELOPMENT & OPERATIONS
    - MANNED/UNMANNED INTERFACES
    - LOGISTICS
  - Training

ROBOTICS: MILITARY TRAINING IMPACTS

DIRECT IMPACTS

* Training Aids/Instructors for Humans
  - EXAMPLE: Robot to Dismantle and Reassemble Engine While Explaining Engine Repair
* Training of Robots
  - COMBAT: Space, Air, Land, Sea
  - SUPPORT: Vehicles, Medics, Cooks, Etc.
* Robot/Human Field Exercises
  - "Brilliant" Targets/Combatants
    - ROBOTIC VEHICLES
    - ANTHROPOMORPHIC ROBOTS/HUMAN SIMULANTS
  - Human/Machine Interfaces and Interactions
  - Highly Realistic
* Training Cost/Time Reductions
* Changes in Training Personnel, Vendors, Facilities

ROBOTICS: MILITARY TRAINING IMPACTS

INDIRECT IMPACTS

- New Skill Categories
- Fewer Personnel
- More/Less Educated Personnel
- Changes in Organization, Composition and Structure of Forces

ROBOTICS: MILITARY TRAINING ISSUES

- **Technology Cost & Reliability**
- **Vested Interests**
  - PSYCHOLOGICAL
  - ECONOMIC
- **Value**
  - TO TRAINING PROGRAM
  - TO COMBAT EFFECTIVENESS
- **Optimum Training System Design and Application**
  - HUMAN FACTORS
  - HUMAN/MACHINE INTERFACES
  - ROBOT DESIGN/APPLICATIONS

ROBOTICS: MILITARY EDUCATION AND TRAINING RESEARCH ISSUES

* Initiate Funding
  - Technology
  - Training Applications for Off-The-Shelf Technology
  - Training Trainers
  - Facilities

* Design Organization
  - Architecture
  - Personnel Types/Quantities
  - Relationships With Other Military/Civilian Organizations

* Develop Trainer/Trainee Criteria
  - Intellectual
  - Psychological
  - Physical

Key U.S. Robotic Weapons Issues

- Vested Interests in Manned Weapons
- Uncertainty of New Technology
- Difficulty of Joint Service Development and Operations
- Difficulty of Operational and Organizational Integration with Existing Systems
- Ad Hoc, Intermittent Support

DR. GEORGE A. MILLER

Some Psychological Perspectives on the Year 2010

SOME PSYCHOLOGICAL PERSPECTIVES ON THE YEAR 2010

Current State of Cognitive Psychology

Potential Significance of Advances

Future Prospects for Psychology and Education

CURRENT STATE OF COGNITIVE PSYCHOLOGY

Perception

Attention

Memory

Imagery

Thought

Language

PERCEPTION

It remained for Gibson to adopt the radical hypothesis of what he called the ecological approach to perception, namely, the hypothesis that under normal conditions, invariants sufficient to specify all significant objects and events in an organism's environment, including the dispositions and motions of those objects and of the organism itself relative to the continuous around, can be directly picked up or extracted from the flux of information available in its sensory arrays.

-- R. N. Shepard (1984)

PERCEPTION

...a word which is backward pattern masked such that it is not only unreportable but also undetectable, nevertheless gains access to a lexical or semantic representation.

-- A. J. Marcel (1983)

...the procedures used to determine thresholds in any study investigating the perception-without-awareness hypothesis must be capable of distinguishing the objective threshold from a subjective threshold. Otherwise, it is *not* possible to determine if the absence of discriminative responding is due to a lack of perceptual sensitivity or to a lack of confidence that a particular stimulus has been presented.

-- J. Cheesman & P. M. Merikle (1984)

ATTENTION

...the ability to divide attention is constrained primarily by the individual's level of skill, not by the size of a fixed pool of resources.

-- W. Hirst et al. (1980)

MEMORY

According to naive realism, our memory stores copies or traces of "stimuli,".... In the constructivist view, we do not remember what we saw, but what we thought. Neither of these approaches can account for all the data.

-- M. K. Johnson (1983)

IMAGERY

Resonance is advanced as a metaphor for how internalized constraints such as those of kinematic geometry operate in perception, imagery, apparent motion, dreaming, hallucination, and creative thinking, and how such constraints can continue to operate despite structural damage to the brain.

-- R. N. Shepard (1984)

THOUGHT

As long as logic was thought to study laws of human reasoning, logicians were expected to explain logical fallacies as well as logical truths. Not until Frege cut this connection was formal logic able to develop, to become one of the outstanding intellectual accomplishments of the 20th century. When A.I. similarly renounces psychologism, it too may take off toward accomplishments we cannot now even imagine.

-- G. A. Miller (1981)

LANGUAGE

Theories of comparative grammar stand in an intimate relation to theories of linguistic development. For, if anything is certain about natural language it is this: children can master any natural language in a few years time on the basis of rather casual and unsystematic exposure to it. This fundamental property of natural language can be formulated as a necessary condition on theories of comparative grammar: such a theory is true only if it embraces a collection of languages that is learnable by children.

-- D. N. Osherson, M. Stob, & S. Weinstein (1984)

CURRENT STATE OF COGNITIVE PSYCHOLOGY

- Perception
- Attention
- Memory
- Imagery
- Thought
- Language
- General Cognition
- Psychometrics

PSYCHOMETRICS

The Broad-Range Tailored Test (BRTT) is a computerized adaptive test developed by Frederic M. Lord. It employs a maximum likelihood selection strategy to choose items from an item pool stored on magnetic disk.... The test-retest reliability of the BRTT was .8719 at the 25th item; reliability of the PSAT verbal score (scaled down to 25 items) was .65.... This finding confirms theoretical expectation regarding the increased efficiency of adaptive, as compared to conventional tests.... Students found the human-computer interface easy to use and less fatiguing than a long pencil-and-paper test.

-- C. B. Kreitzberg & D. H. Jones (1980)

POTENTIAL SIGNIFICANCE OF ADVANCES

Selection

Training

Communication

Supernormal Messages

FUTURE PROSPECTS FOR PSYCHOLOGY AND EDUCATION

Technological Assumptions

Implications for Psychology

Implications for Training

Implications for Psychometrics

TECHNOLOGICAL ASSUMPTIONS

- National Networks
- Natural Language Interface
  - Knowledge base
  - Large vocabulary
  - Reasoning ability
  - Speech synthesis and recognition
  - Image processing
- Parallel Processing

NATIONAL NETWORKS

In the nineties, the "computer" as a distinct object will begin to disappear. The bus-speed network links will expand from the currently possible local networks to approach a global Worldnet. This network will have a very different character from the global telephone network. Users of any appropriate terminal plugged into the Worldnet will have complete access to any permissible information source just as though they were directly connected to it.

-- B. R. Schatz (1984)

NATURAL LANGUAGE INTERFACE

Large Knowledge Base

Large Vocabulary

Reasoning Ability

Speech Processing

Image Processing

PARALLEL PROCESSING

The general notion of massively parallel models in AI is quite new, and we do not yet understand where its ultimate strengths and weaknesses will lie. We do know that the development of highly parallel computers will have a marked effect on the practicality of connectionistic approaches to AI.

-- J. A. Feldman (1985)

IMPLICATIONS FOR PSYCHOLOGY

- Visual Perception
- Memory
- Thought
- Language

VISUAL PERCEPTION

...the biological system, somewhat embarrassingly, embodies solutions to problems that still plague vision researchers. This situation has lured researchers to tackle the problem of modeling the human visual system head-on, in the hope of discovering its secrets. Such researchers typically have a wide range of cross-disciplinary interests and are joining to make progress in the separate fields of psychology, neuroscience, and computer science.

-- D. H. Ballard & C. M. Brown (1985)

MEMORY

The brain is an incredibly powerful computer. The cortex alone contains over 10^{10} neurons, each connected to thousands of others. All of your knowledge is probably stored in the strengths of these connections.... Perhaps brains have evolved to be very good at a particular style of computation that is necessary in everyday life but hard to program on a conventional computer. Perhaps the fact that brains store knowledge as connection strengths makes them particularly adept at weighing many conflicting and cooperating considerations very rapidly to arrive at a common-sense judgment or interpretation.

-- G. E. Hinton (1985)

IMPLICATIONS FOR TRAINING

Intelligent Computer-Aided Instruction

Access to Computers

IMPLICATIONS FOR PSYCHOMETRICS

New Horizons for Testing

DR. ROBERT G. JAHN and BRENDA J. DUNNE

Engineering Anomalies Research:
Consciousness, Creativity, and the Horizons
of High Technology

Engineering Anomalies Research

Potential Vulnerability of Physical Devices, Systems, and Processes to Anomalous Influences of Human Consciousness

An Engineering Perspective

- Topics of short- and long-term relevance to engineering
- Amenability of topics to rigorous study
- State-of-the-art equipment and techniques
- Focus on physical and technical parameters
- Only common operators, anonymous and uncompensated
- Address professional communities

Program Configuration

I. Operator-Related Anomalies in Random Physical Systems

Interactions of human consciousn ical devices and processes yielding anomalous s or

II. Precognitive Remote Perception

Acquisition of information about geographical targets remote in distance and time, and inaccessible by known sensory channels

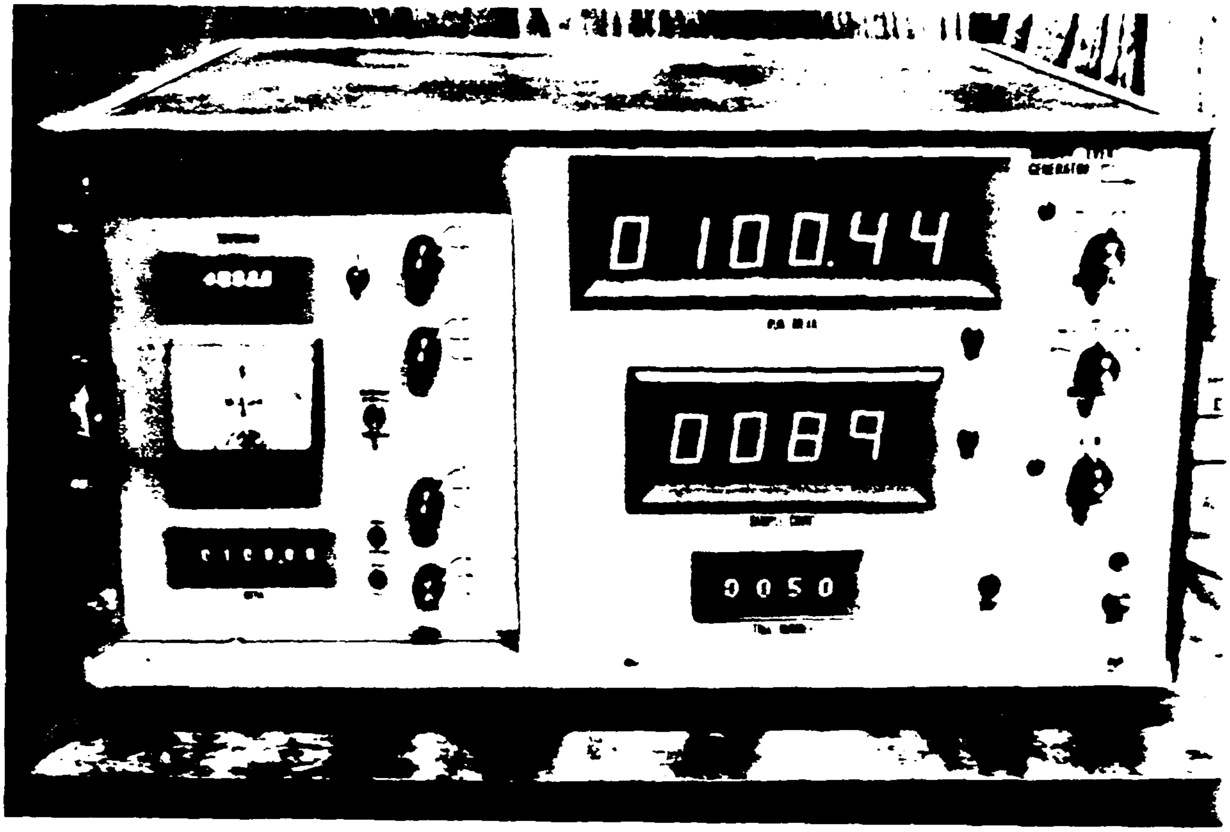
III. Theoretical Model

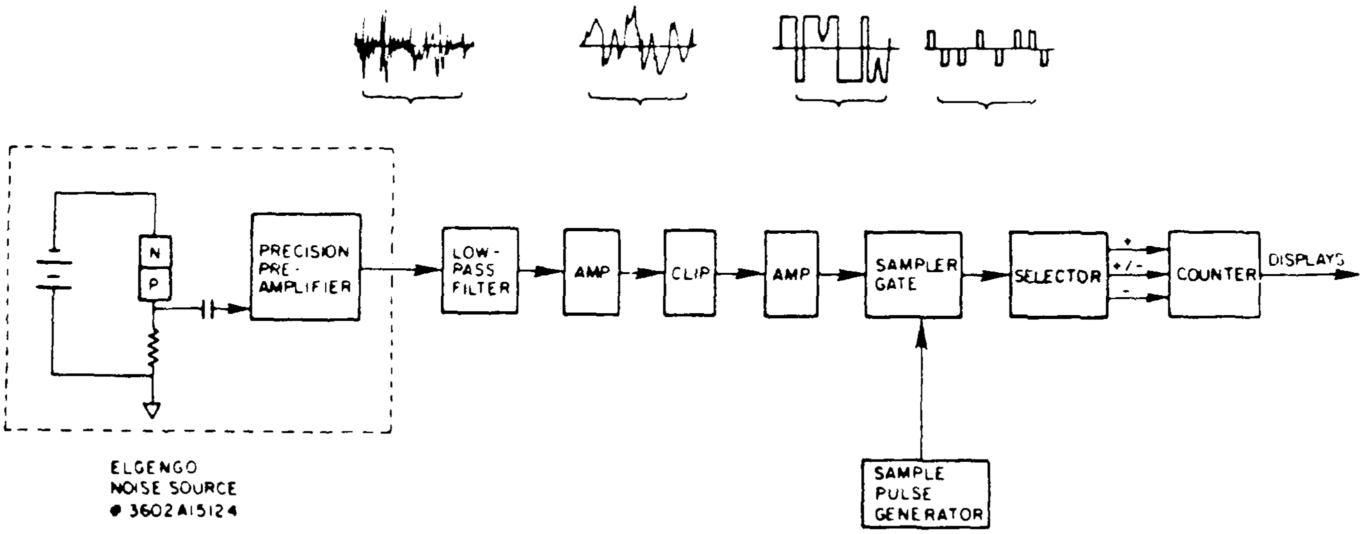
- Correlate Data
- Develop more effective experiments
- Explicate phenomena on fundamental grounds

I. Operator-Related Anomalies in Random Physical Systems

Various Mechanical, Electrical, Optical, Thermal Devices Employed in Numerous Experiments Having Common Features:

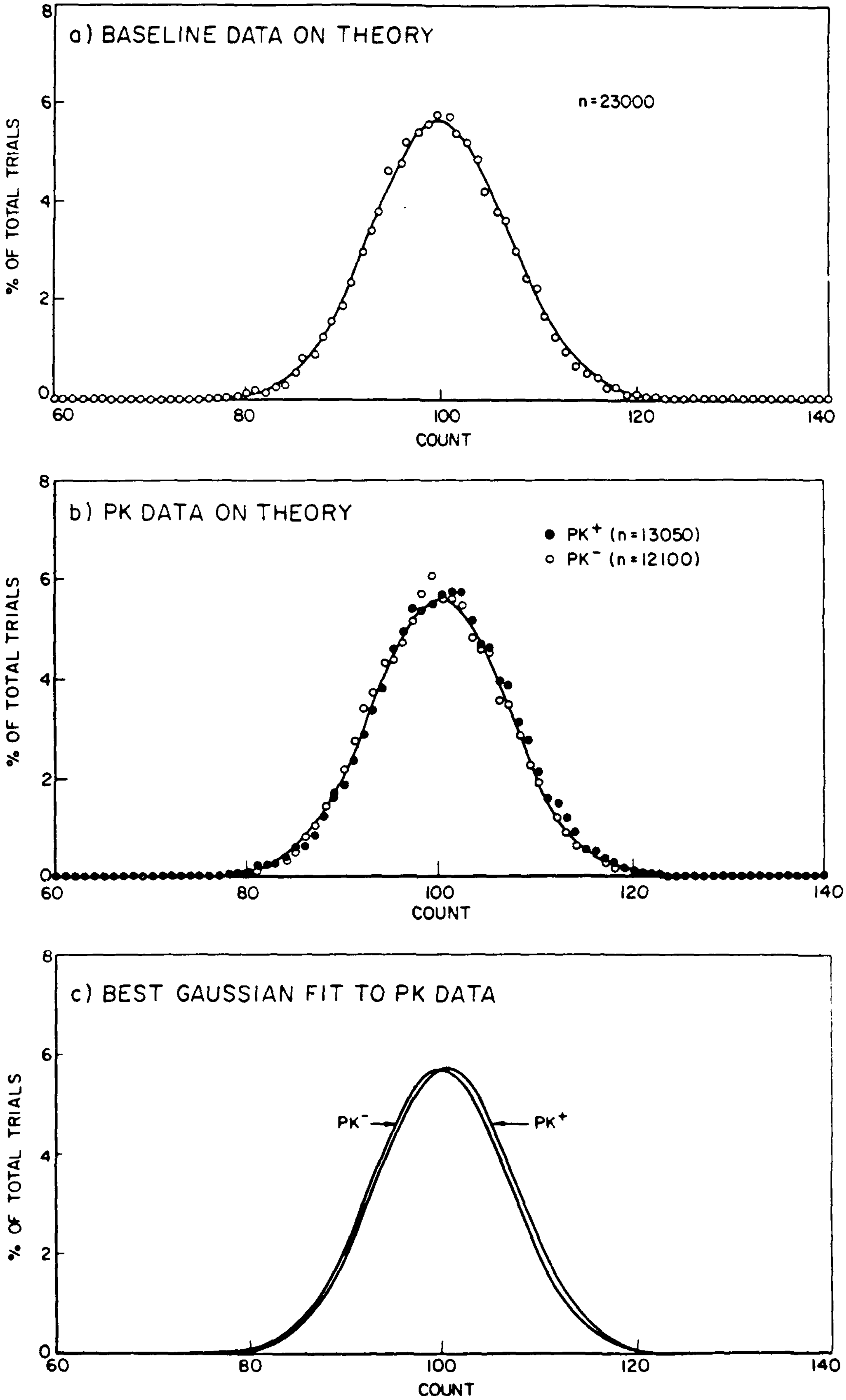
- Based on random physical process
- Baseline distribution of output well established
- Extensive protection against artifact
- On-line data collection; redundant recording
- Immediate, intermediate, and terminal feedback for operator
- Controlled, tri-polar operational protocols



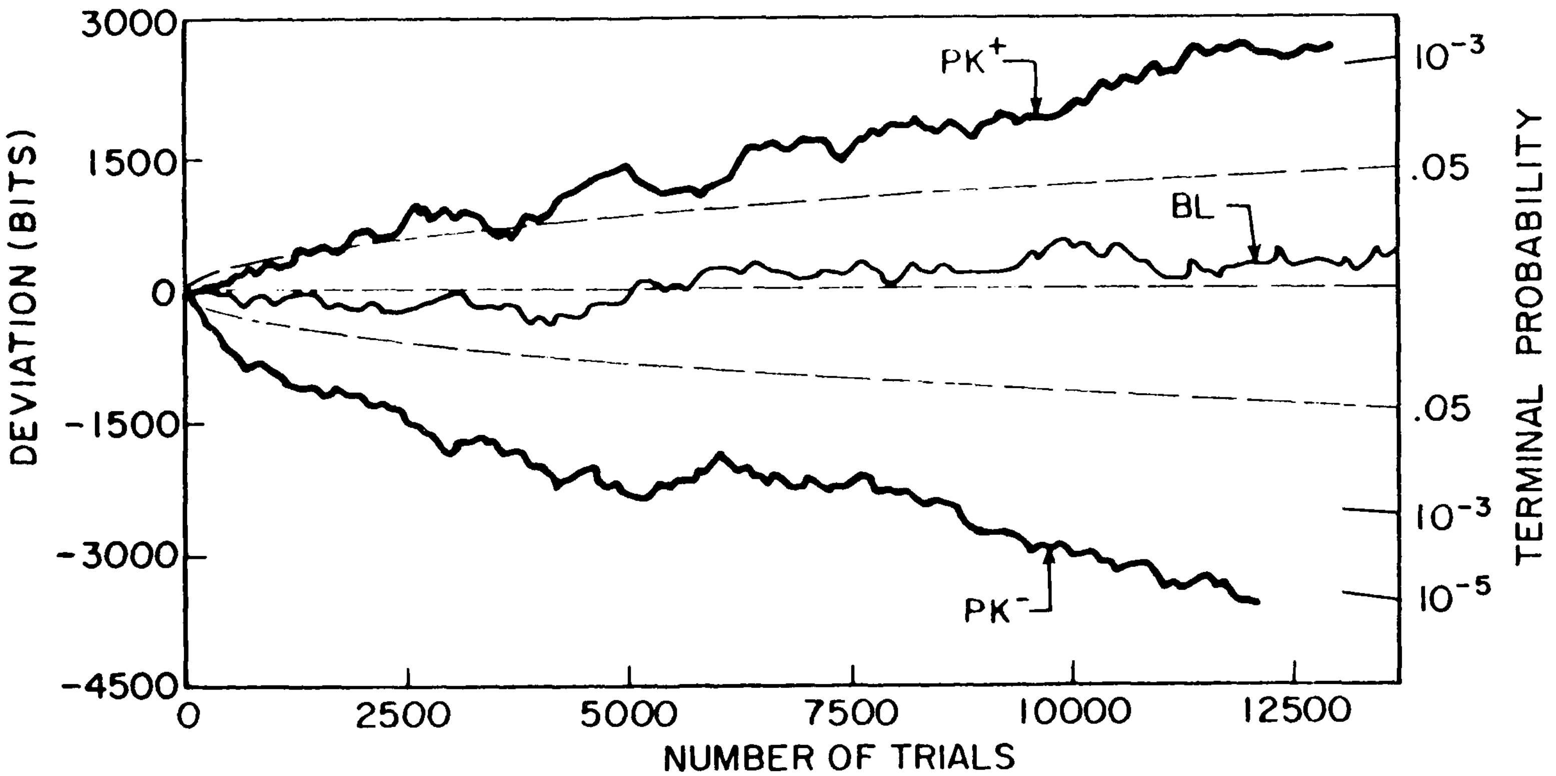


FUNCTIONAL DIAGRAM

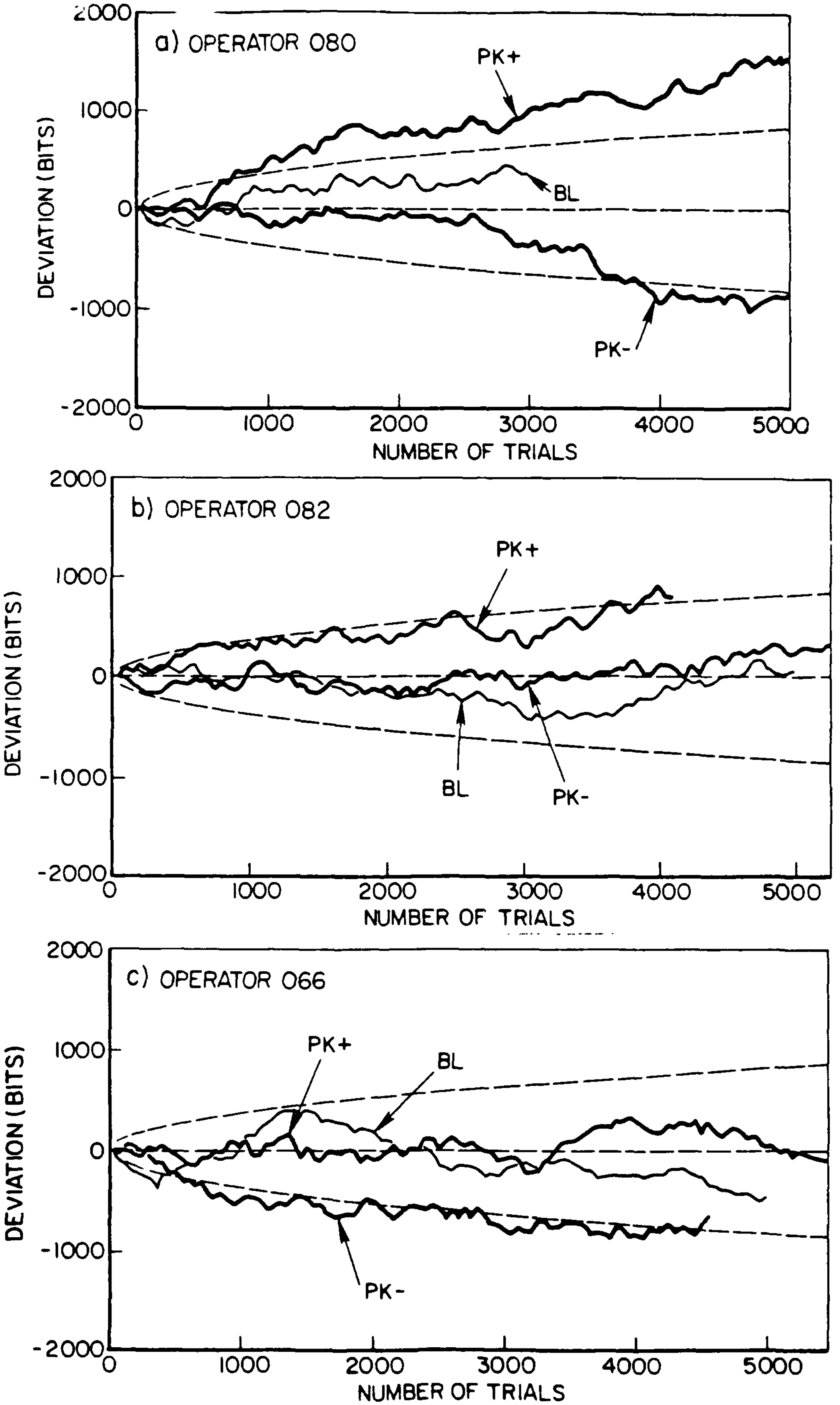
ELECTRONIC RANDOM EVENT GENERATOR



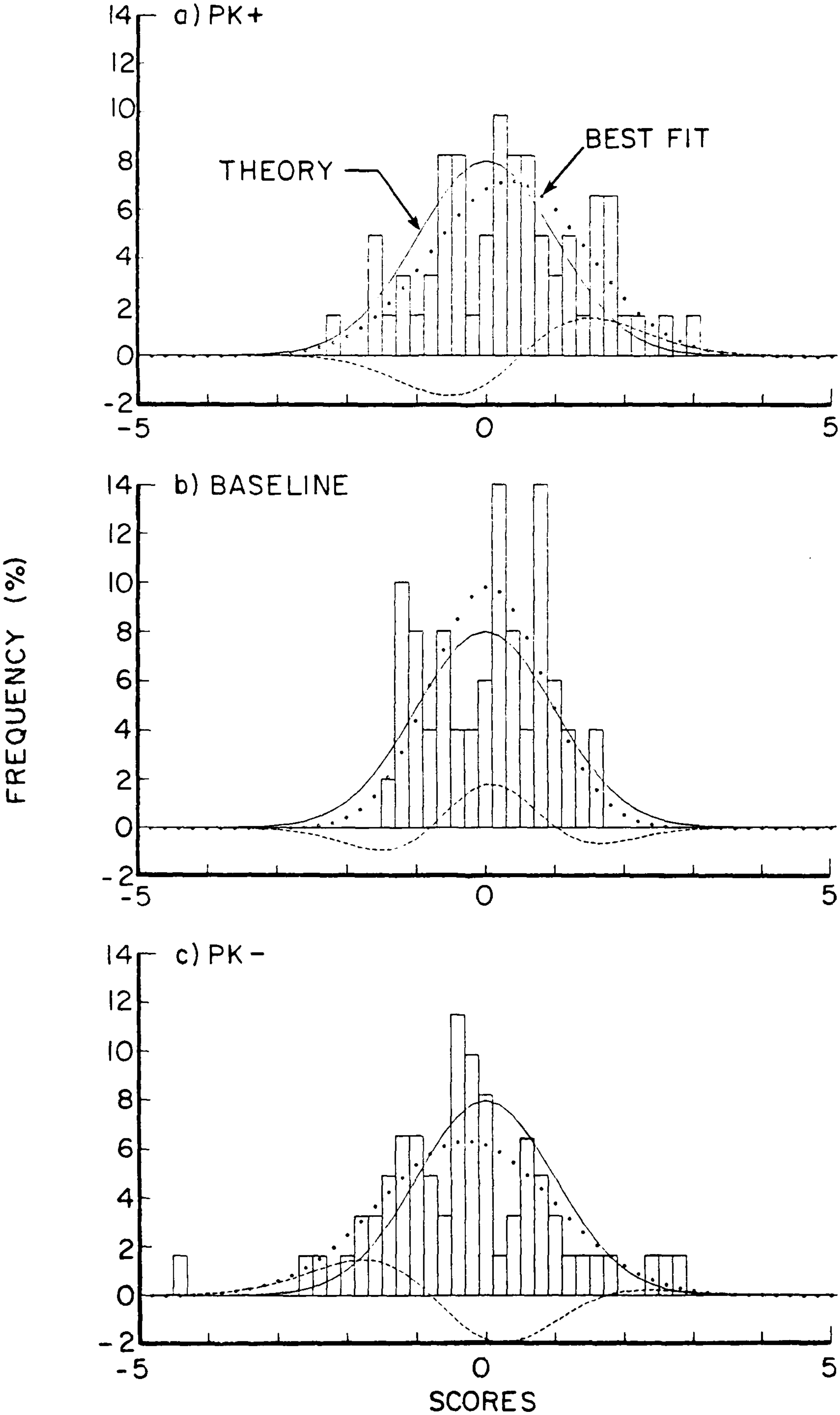
REG FREQUENCY OF COUNT DISTRIBUTIONS



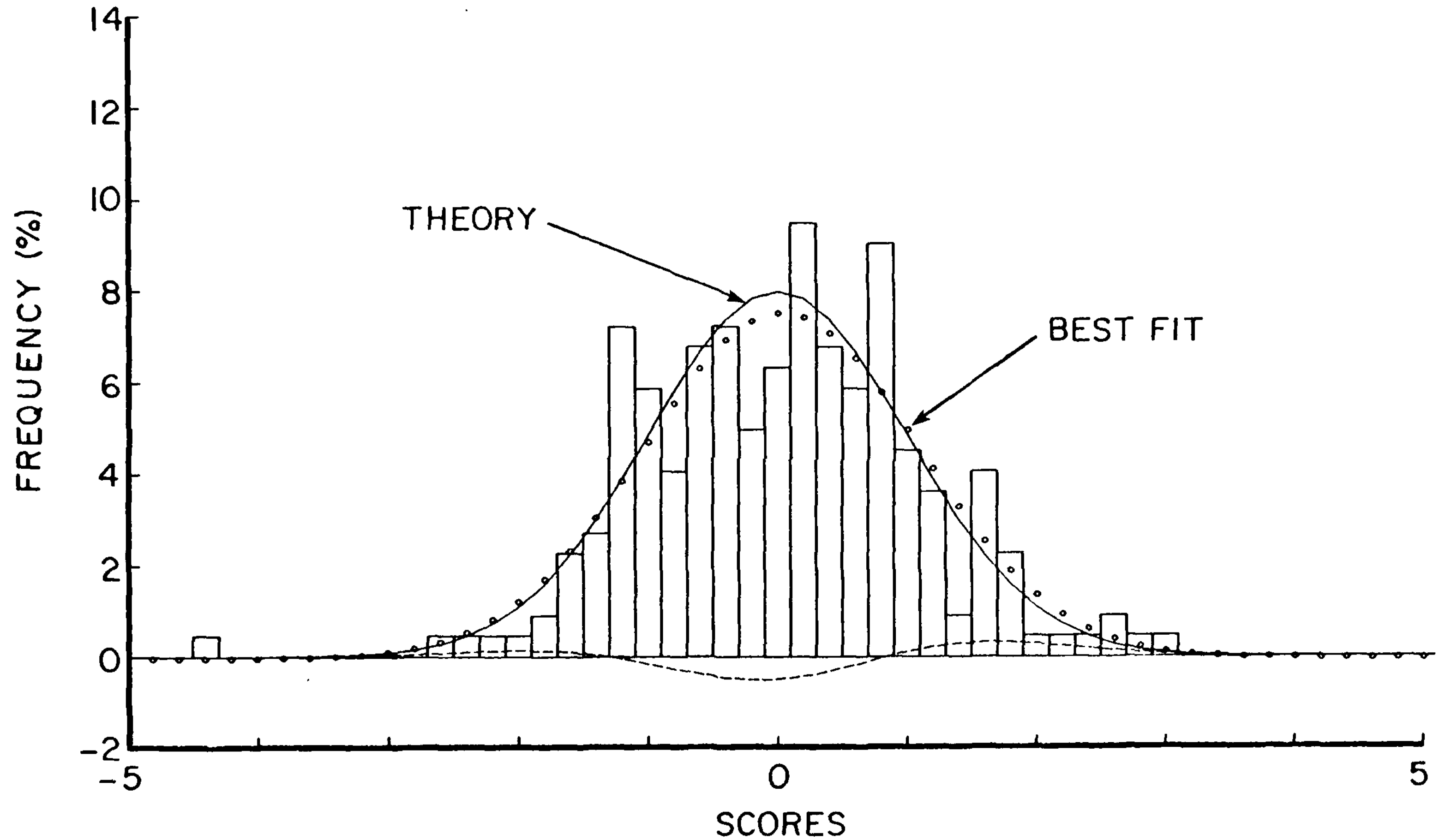
REG CUMULATIVE DEVIATIONS FROM THEORETICAL MEAN
(OPERATOR 010)



REG CUMULATIVE DEVIATIONS FROM THEORETICAL MEAN: VARIOUS OPERATORS

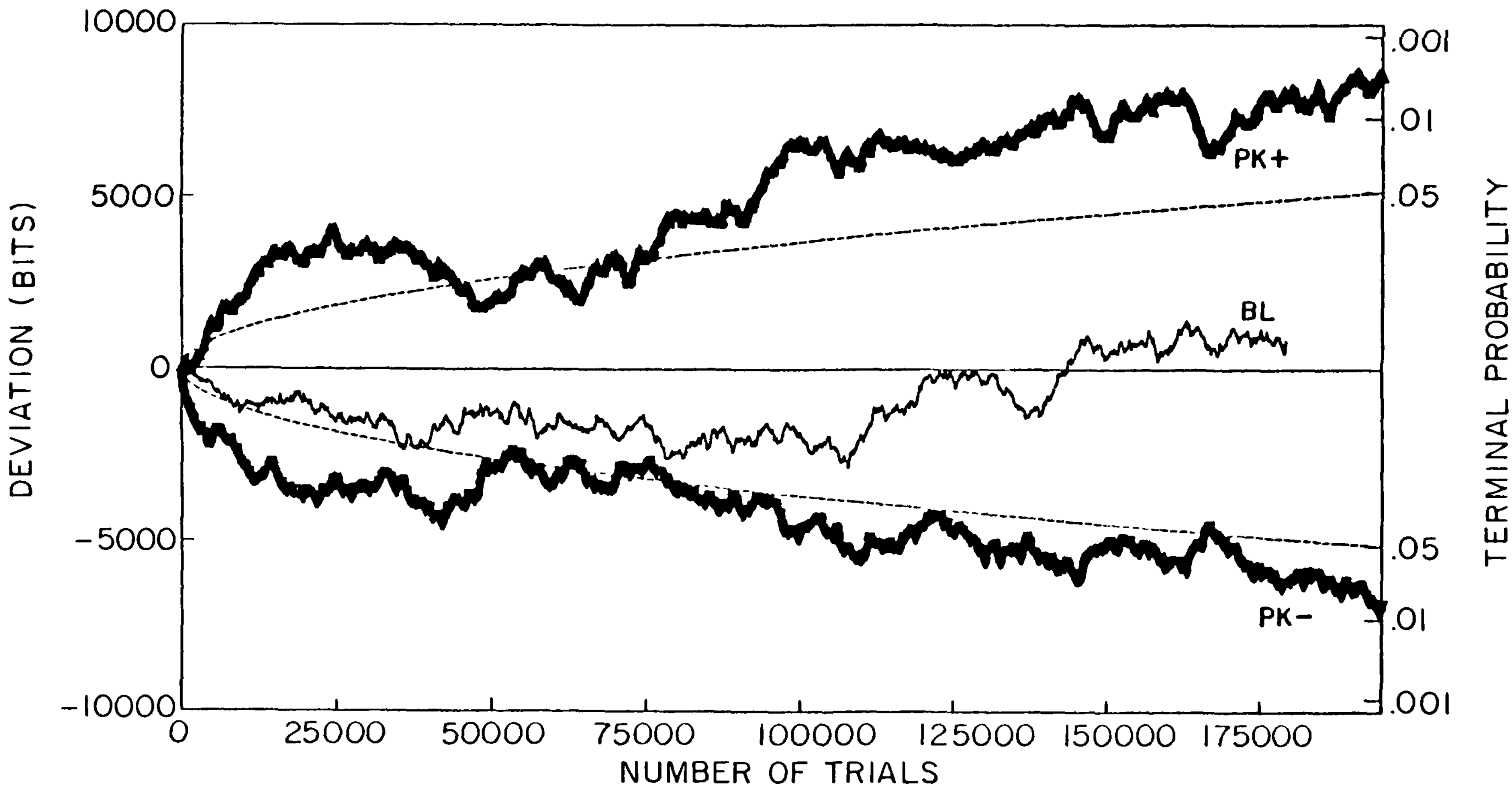


REG: FREQUENCY OF SERIES t-SCCRES

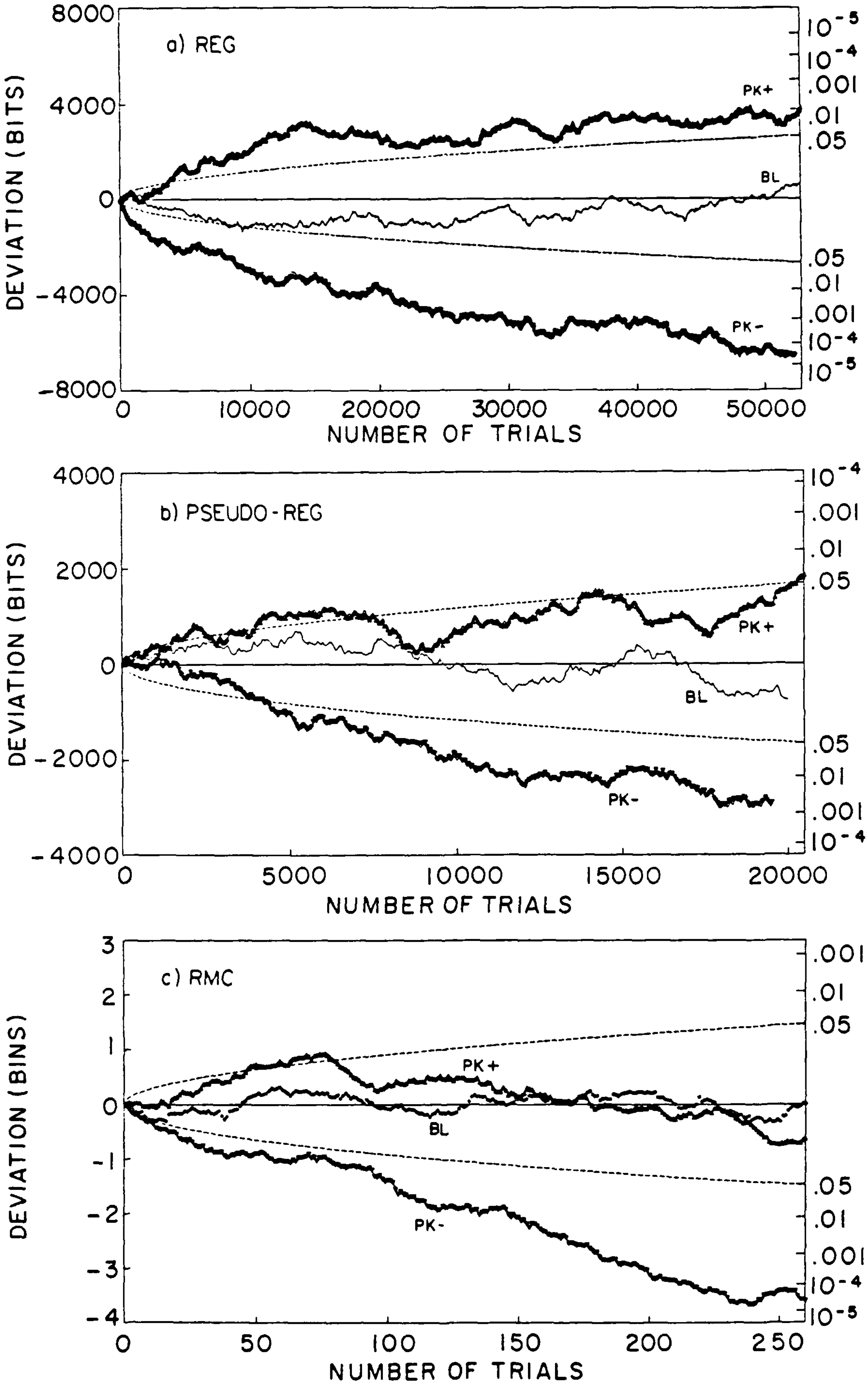


REG: FREQUENCY OF SERIES t - SCORES
BALANCED TOTAL DATA BASE

8-5-28



REG CUMULATIVE DEVIATIONS FROM THEORETICAL MEAN:
ALL DATA



CUMULATIVE DEVIATIONS (010)
3 DEVICES

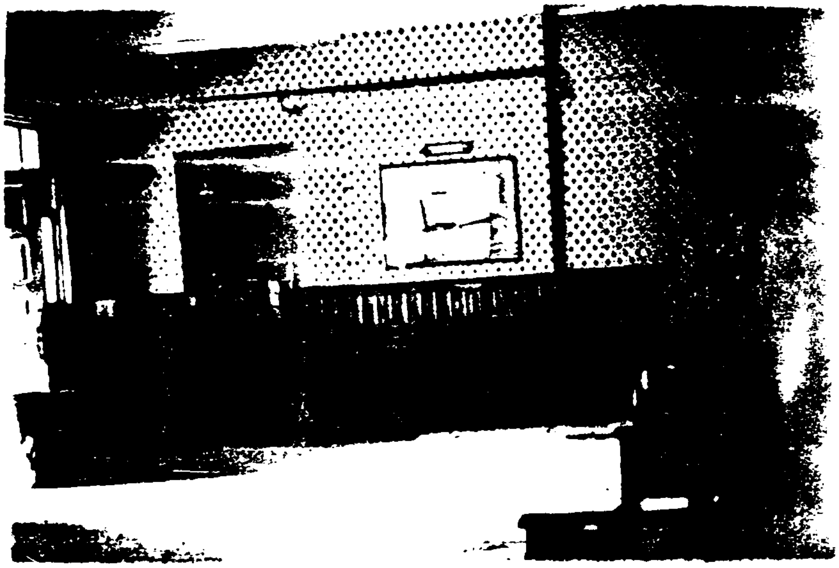
REG Summary

- Operator-specific signatures of achievement
- Secondary dependence on experimental conditions
- Little dependence on specific device
- 25% of individual operator data bases significant
- *Overall data base significant* ($p < 10^{-4}$)
  - 22 operators
  - 61 complete series
  - 500,000 trials (10^8 bits)
- Results typical of other experiments (cf RMC)
- Results challenge mechanistic model

II. Precognitive Remote Perception

Experimental Protocol:

- Percipient/agent/target
- Spatial and temporal parameters
- Free-response transcripts
- Target/perception encoding
- Analytical evaluation algorithms



Target: NWRR station, Glencoe, Illinois. The percipient was some five or six miles away. The perception, generated 35 minutes precognitively, reads, in part:

"...I see a train station, one of the commuter train stations that's on the expressway...I see a train coming....See just the front end of the train station. See a little bit within it. I think there are wooden planks on the floor. I hear like the clicking...of feet or shoes on the wooden floor...There are posters or something up, some kind of advertisements or posters on the wall in the train station. I see the benches. Getting the image of a sign, but I think it's probably the sign of what station it is. It's about 8 or 10 letters in the word. Maybe something like Clydeburn or Clayburn. Have the impression of this wooden floor being somewhat littered, just sort of dirty. I see the tracks. No train on the tracks right now. Empty tracks..."

Target: Ruins of Urquardt Castle, Loch Ness, Scotland. The percipient was in New York City, some 3500 miles away. The perception, generated 14 hours retrocognitively, reads:

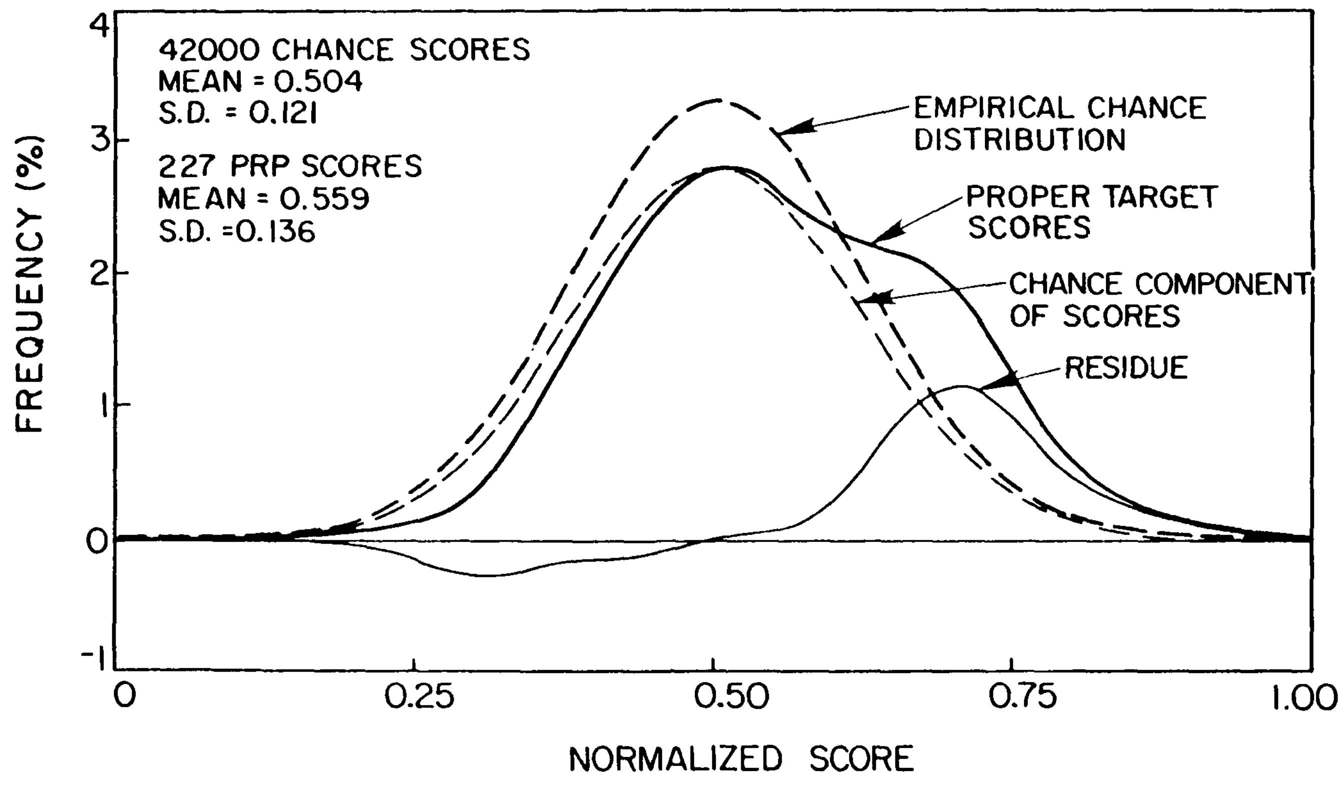
"Rocks with uneven holes. Also smoothness. Height. Ocean. Dark. Dark blue. White caps. Waves booming against rocks? On mountain or high rocks overlooking water. Dark green in distance. Gulls flying? Pelican on a post. Sand. A lighthouse? Tall structure. Round with a conical roof. High windows or window space with a path leading up to it. Or a larger structure or a castle." (Here there is a sketch of a castle abutment on the transcript.) "Old. Unused. Fallen apart. Feeling musty, or dark. Moss or grass growing in walls. Wood draw bridge? A black dog? With longish curly hair. Flowers? Ocean smells. Snow. Ice-capping a mountain. High large cavernous hall. Castle. Strong positive emotional response."

Target: Tretiakovskaia Gallereia, Moscow, U.S.S.R. The percipient was in Wisconsin, some 4500 miles away. The perception, generated 24 hours precognitively, reads, in part:

"Have the sensation of being in a very quiet, sombre, subdued sort of atmosphere....Any color impressions I get are the same--greys, browns, dark subdued colors. I feel an oldness....I'm thinking of a large church or something, or a castle. Some kind of building. It seems to be quite large. Sensation of sounds echoing, subdued colors....I see several, maybe two to four round balls that seem to be on top of something. Maybe it's some kind of decoration. Like on top of something that's of a generally square shape. Almost like a square column with a ball on top. I have a very clear picture suddenly of an old building. It's quite large. There are windows with, like, arches. They may not be exactly arched; the arches come to a point on top, almost. Very impressive. It's a light grey color, very ornate. It comes to a point of some sort, but it's not a regular point. Like where it should be round on top it comes to a point. I'm not sure if it's windows or the shape of the building itself....Great big double doors....Just saw those square pillars with the balls on top again. They seem to be almost like an entranceway, one on either side...."

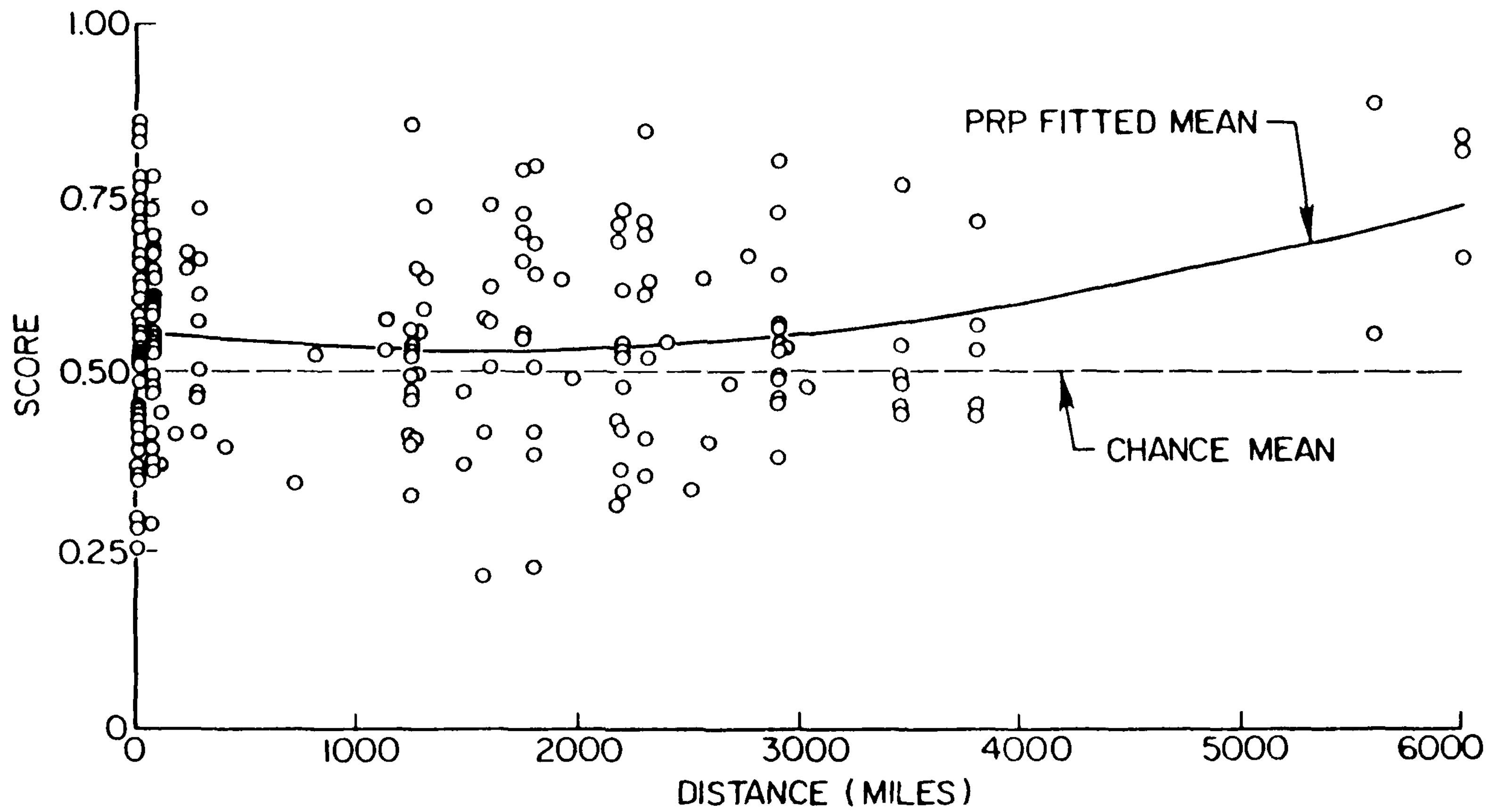
Target: Danube River, Bratislava, Czechoslovakia. The percipient was in Wisconsin, some 5600 miles away. The perception, generated 24 hours precognitively, reads, in part:

"I have the feeling that the (agent) is somewhere near water. I seem to have the sensation of a very large expanse of water. There might be boats. Several vertical lines, sort of like poles. They're narrow, not heavy. Maybe lamp posts, or flag poles. Some kind of circular shape. Almost like a merry-go-round or gazebo, a large round thing. It's round, on it's side, like a disk; it's like a round thing, flat on the ground, but it seems to have height as well. Maybe with poles. Could possibly come to a point on top. Seeing vertical lines again. Seems to be a strong impression, these vertical lines...Predominant colors seem to be blue and green... Water again...Some very quick impression of a fence, a low fence... Steps seem to go up to some kind of...fence. It's a dark fence, and it's along like a walk sort of at the top of the steps. The steps sort of lead up to like a path or walkway. Like a boardwalk. And there's a fence along it. There's people walking along it, and there's vertical lines along that walkway..."



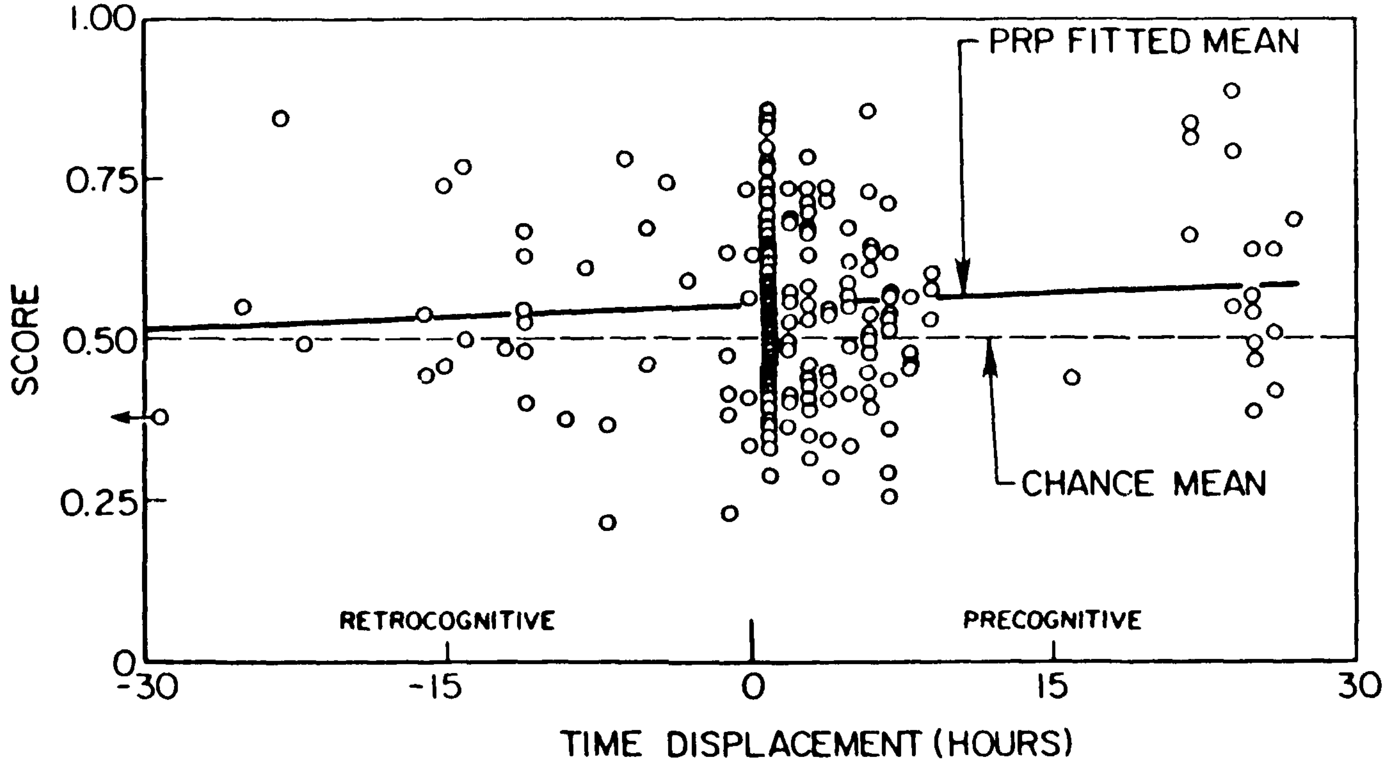
PRP SCORE DISTRIBUTIONS
(METHOD B)

337



PRP SCORES AS FUNCTION OF DISTANCE
(METHOD B, FORMAL, N=227)

338



PRP SCORES AS FUNCTION OF TIME DISPLACEMENT
(METHOD B, FORMAL, N = 227)

PRP Summary
(> 400 Trials)

- Overall yield highly significant
- Broad range of fidelity
- Characteristic distortions of perceptions
- Negligible spatial dependence, up to global distances
- Negligible temporal dependence, up to several days

III. Theoretical Model

Experimental Data Will Not Support Simple Transposition of Existing Physical Theory

Suggest Reconsideration of Basic Premises About the Nature of Reality:

- Reality/experience constituted only in the interaction of consciousness with its environment
- Currency of reality is information, which flows in either direction
- Concepts commonly invoked to describe an environment also reflect the characteristics of consciousness
- "Particulate" image of consciousness should be complemented by a more general *"wave-mechanical" conceptualization*

Quantum-Mechanical Metaphor

Schrödinger Formalism Applied to Define:

- Consciousness “atoms”
- Consciousness “molecules”
- Information processes
- Consciousness “principles”:
  - Uncertainty
  - Superposition
  - Exclusion
  - Correspondence
  - Indistinguishability
- Consciousness quantum statistics
- Other “anomalous” effects

Applications and Implications

Short Term

- Vulnerability of low-level signal processing equipment
  - Data processing
  - Control systems
- Anomalous information acquisition
  - Intelligence
  - Law enforcement
  - Prospecting
  - Forecasting

Applications and Implications

Longer Term

cf Committee on Science and Technology Report to U.S. House of Representatives (June 1981):

"...A general recognition of the degree of interconnectedness of mind with other minds (and with matter) could have far-reaching social and political implications for this Nation and the world."

- Horizons of high technology
- Personal creative processes
- Extraordinary human capabilities
- Social value systems
- Educational strategies

Implications for Education

Contemporary Situation:

Formal strategies

- Linear/deductive
- Causal/deterministic
- Analytical/quantitative
- Reductionistic/specialized
- Newtonian/"particulate"
- Objective

Informal initiatives

- Interdisciplinary curricula
- Creativity training
- Personal realization programs
- Holistic approaches
- Counseling and therapy

Implications for Education

Future Scenario

Best aspects of contemporary subsumed in new plan, but greatly computer-facilitated.

Balanced by expansion of philosophical perspectives and epistemological premises, e.g.:

- "Particulate" ⟷ "wave-mechanical" views of reality
  - Personal perspective
  - Interpersonal resonances
  - Extended interactions
- Arbitrariness and limitations of Newtonian concepts
  - Sanctity of space/time relaxed
  - Alternative coordinates and multiple frames of reference
- Subjective/impressionistic/aesthetic parameters
  - Consciousness "metric"
- Active consciousness/environment dialogues
  - Participatory reality
  - Opportunity/responsibility

Benefits

Expansion of fundamental knowledge

- New basic data
- Broadening of scientific paradigm

Pragmatic utilization

- Creative capacities
- Modulation of artificial intelligence systems
- Advanced human factors engineering

Humanistic benefits

- Alter individual and collective perception of human state
- Improve value systems and behavior patterns
- Evolutionary enhancement

DR. HENRY HALFF

<u>Government Research and Development Efforts Related to Training Technology</u>

GOVERNMENT RESEARCH AND DEVELOPMENT EFFORTS RELATED TO TRAINING TECHNOLOGY

Henry M. Halff

Halff Resources, Inc.

13 JUNE 1984

349

Credits

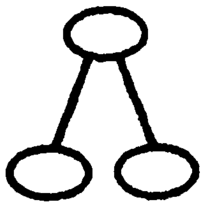
Mr. Henry W. Conner (GAO)
Dr. Richard Johnson (OSTP)
Mr. Tony Kraemer (GAO)
Dr. Fred Weingarten (OTA)
Dr. Julie Goerte (OTA)
Dr. Gretchen Kolsrud (OTA)
Dr. Wayne Shybilske (NAS/NRC)
Dr. Stan Deutsch (NAS/NRC)
Dr. Dennis Miller (NAS/NRC)
Dr. Vern Miles (NAS/NRC)
Dr. Dean Gerstein (NAS/NRC)
Dr. Alexandra Wigdor (NAS/NRC)
Dr. Tom Carroll (NIE)
Dr. Hunter Moorman (NIE)
Dr. Barbara Richardson (NIE)
Dr. Nevzer Stacey (NIE)
Dr. Sylvia Shafto (NIE)
Dr. Arthur Melmed (DOE)
Dr. Howard Hjelm (DOE)
Dr. Frank Withrow (DOE)
Dr. Jean Narayanan (DOE)
Dr. Richard Louttit (NSF)
Dr. Joseph Young (NSF)
Dr. Robert Rabin (NSF)
Dr. James Larimer (NSF)
Dr. Joel Colton (NSF)
Dr. Nathaniel Pitts (NSF)
Dr. Jean Lauder (NSF)
Dr. Elliott Jacques

Dr. Fred Stolnitz (NSF)
Dr. Andrew Molnar (NSF)
Dr. Robert Abeles (NIH)
Dr. Leonard Jakubczak (NIH)
Dr. Rachel Levinson (NIH)
Dr. Stephen Koslow (NIMH)
Dr. Barry Lebowitz (NIMH)
Dr. Dominic Santarpia (NASA)
Dr. Judith Orasanu (ARI)
Dr. Owen Jacobs (ARI)
Dr. Ray Perez (ARI)
Dr. Steven Zornetzer (ONR)
Dr. Michael Marron (ONR)
Dr. Susan Chipman (ONR)
Dr. John Tangney (AFOSR)
Dr. William Berry (AFOSR)
Major Hugh Burns (AFHRL)
Dr. Martha Polson (AFHRL)
Major Jack Thorpe (DARPA)
Dr. Ira Skurnick (DARPA)
Capt. Paul Chatelier (DoD)
Mr. Robert Warren (NAVAIR)
Dr. Steve Sellman (DoD)
Mr. Tom Sicilia (TDAC)
Dr. Jesse Orlansky (IDA)
Dr. Cynthia Null (FBPCS)
Ms. Lisa Carlson
Dr. Paul Levinson (Farleigh-Dickinson University)
Dr. James McAlear (Gentronics)

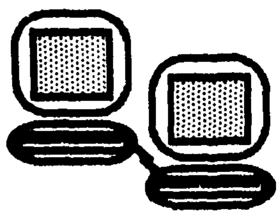
Scientific and Technological Areas

Biotechnology

Neural Sciences



Cognitive Sciences



Electronic Technology
for Training

Biotechnology

Present

Recombinant DNA

Monoclonal Antibodies

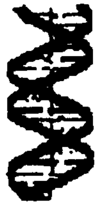
CBW and
CBW Defense

Computation &
Molecular Genetics

Computational
Biotechnology

Neural Prostheses

Future



Biotechnology

Where is the government active?

- **Agriculture**
- **Medicine**
- **Industry**
- **Biological Computation**
  - (behavioral applications)

Neural Sciences

<u>Neurochemistry & Pharmacology</u>

- Pharmacology and Learning Disabilities
- Biological readiness for instruction

<u>Neural Models of Computation</u>

- Modeling of human information processing
- Parallel computation in training technology

Neural Sciences

Government R&D Programs

DARPA

- Technology demonstrations of parallel computation

AFOSR

- Bioreactivity
- Adaptive Networks

ONR

- Learning & Memory
- Biological Intelligence

Neural Sciences

Government R&D Programs
(continued)

NSF

- Molecular and Cellular Biochemistry
- Sensory, Physiology, & Perception
- Integrative Neural Systems
- Developmental Neurosciences
- Psychobiology

NIMH

- Biochemical & biophysical basis of neural function
- Pharmacological & nutrional aspects of neural function

Cognitive Science

<u>What we know about skills</u>

- The importance of models
- The myth of general skills

<u>Cognition, AI, and Training</u>

- Automated tutors & job aids
- Limitations of the field

Cognitive Science

Government R&D Programs

ARI

- Cognition and instruction

NIE

- Cognitive aspects of instruction in schools
- Reading

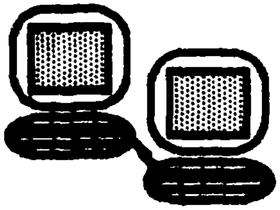
NSF

- Memory and cognitive processes
- Science, math, & engineering education

ONR

- Cognition & real world skills
- Automated tutoring

Electronic Technology for Training



Simulation and the new fidelity

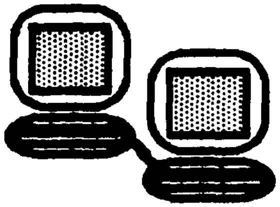
- The training experience
- Conceptual fidelity
- Cost-fidelity tradeoffs

The Social Nature of Training

- Technology and human resources
- The community in training

Curriculum Development

- New elements in curricula
- Automating the development process



Electronic Technology for Training

Government R&D Programs

NSF

- Science & Engineering Education

NIE

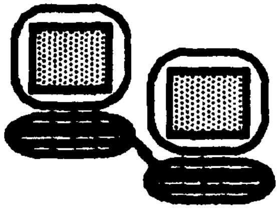
- Education Technology Center

ED

- Educational Technology

DARPA

- SIMNET



Electronic Technology for Training

Service Laboratories

<u>ARI</u>

- Automated tutors for maintenance

<u>AFHRL</u>

- Training and job aiding for maintenance

<u>NPRDC</u>

- STEAMER
- CBMS

<u>NTEC</u>

- Automating Instructor Functions

Conclusions

Where's the plan?

- There isn't any.

Why not?

- The Rigney Principle
- Size, time, and certainty

So what should we be doing?

- Look for solutions to present problems
- Look for solutions to future problems
- Look for technological opportunities
- Support basic research

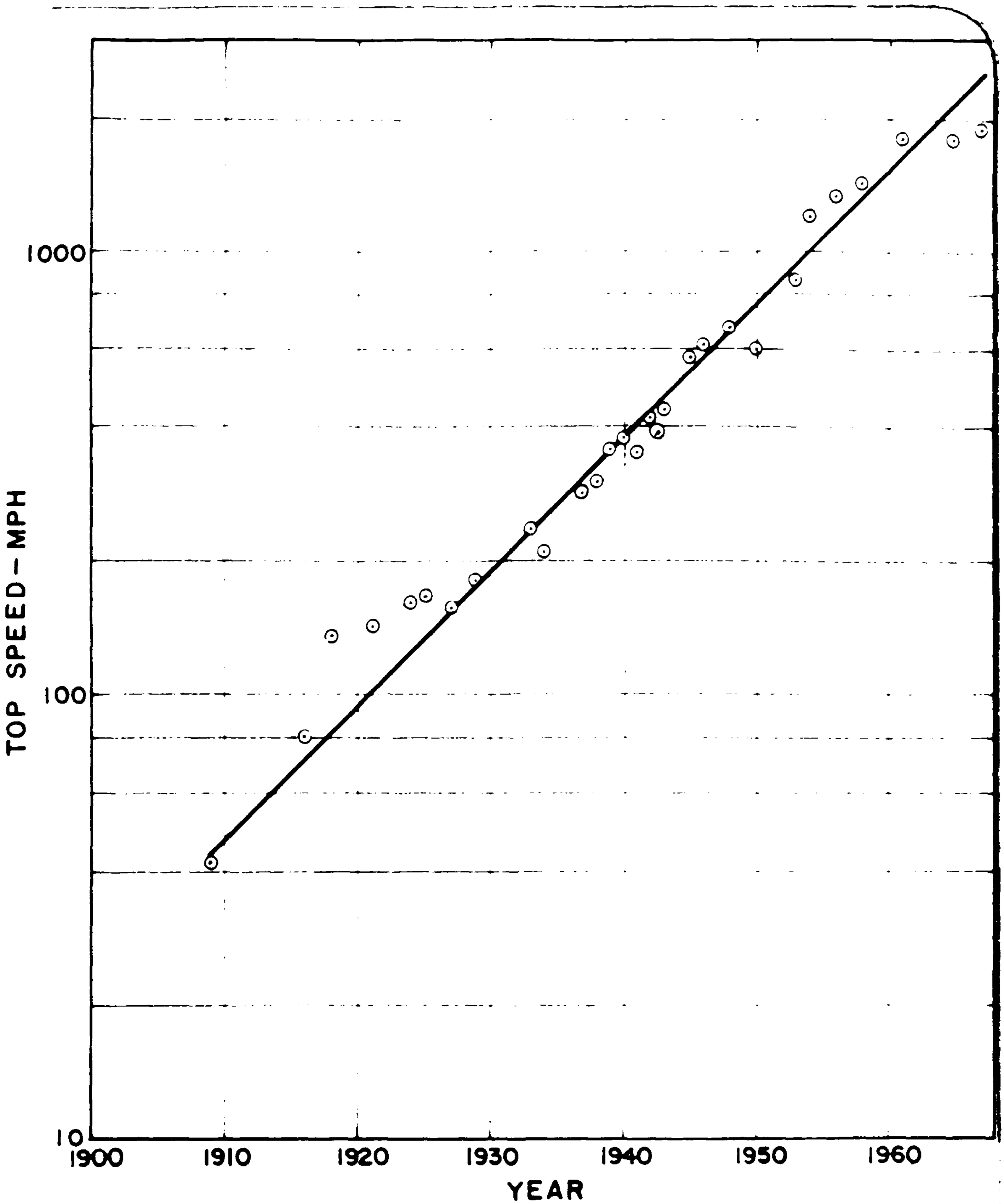
The Rigney Principle

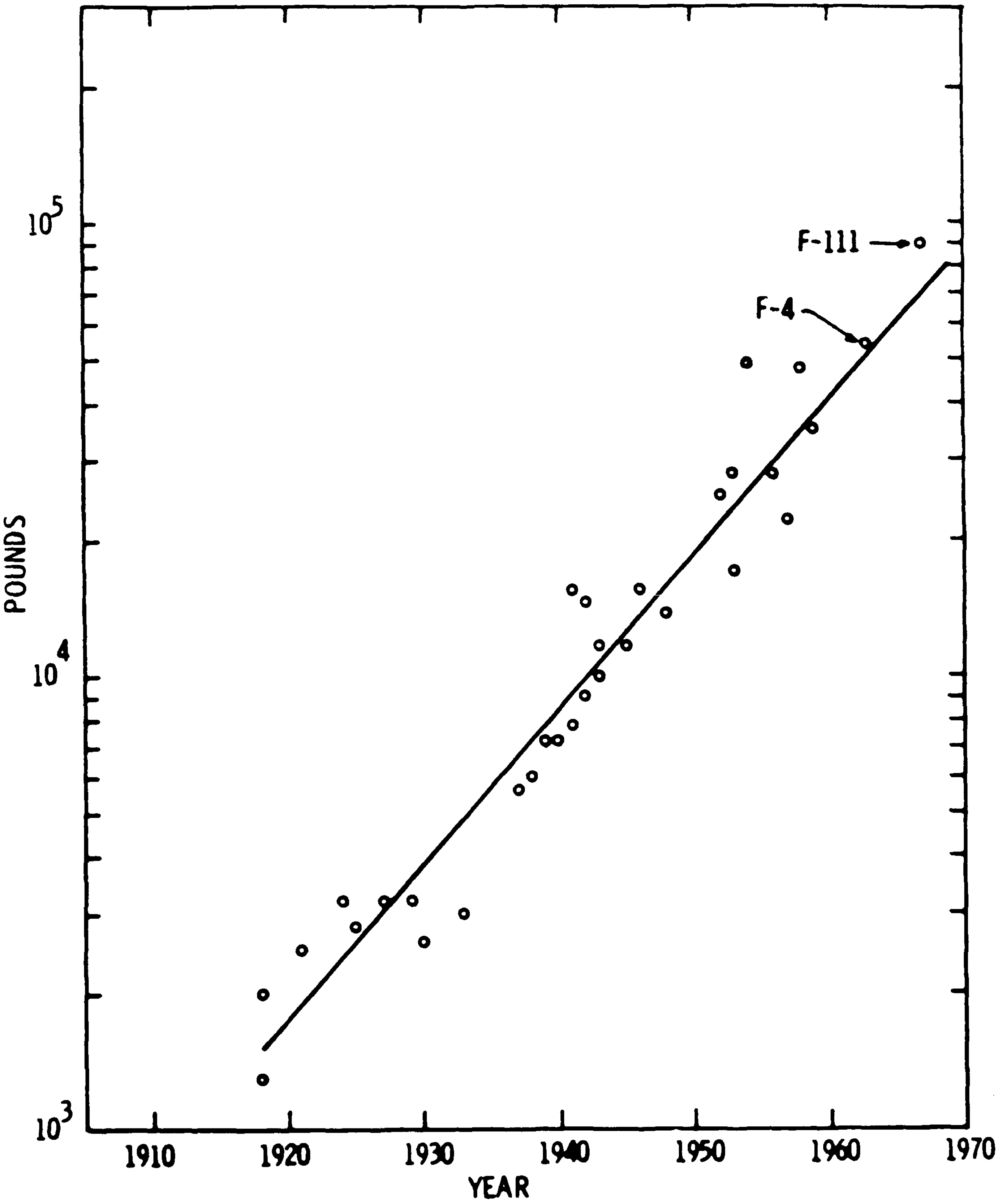
Bright ideas spring from bright minds, and cannot be ordered up on demand by OPNAV Instructions, Army or Air Force Regulations, or similar bureaucratic fiats.

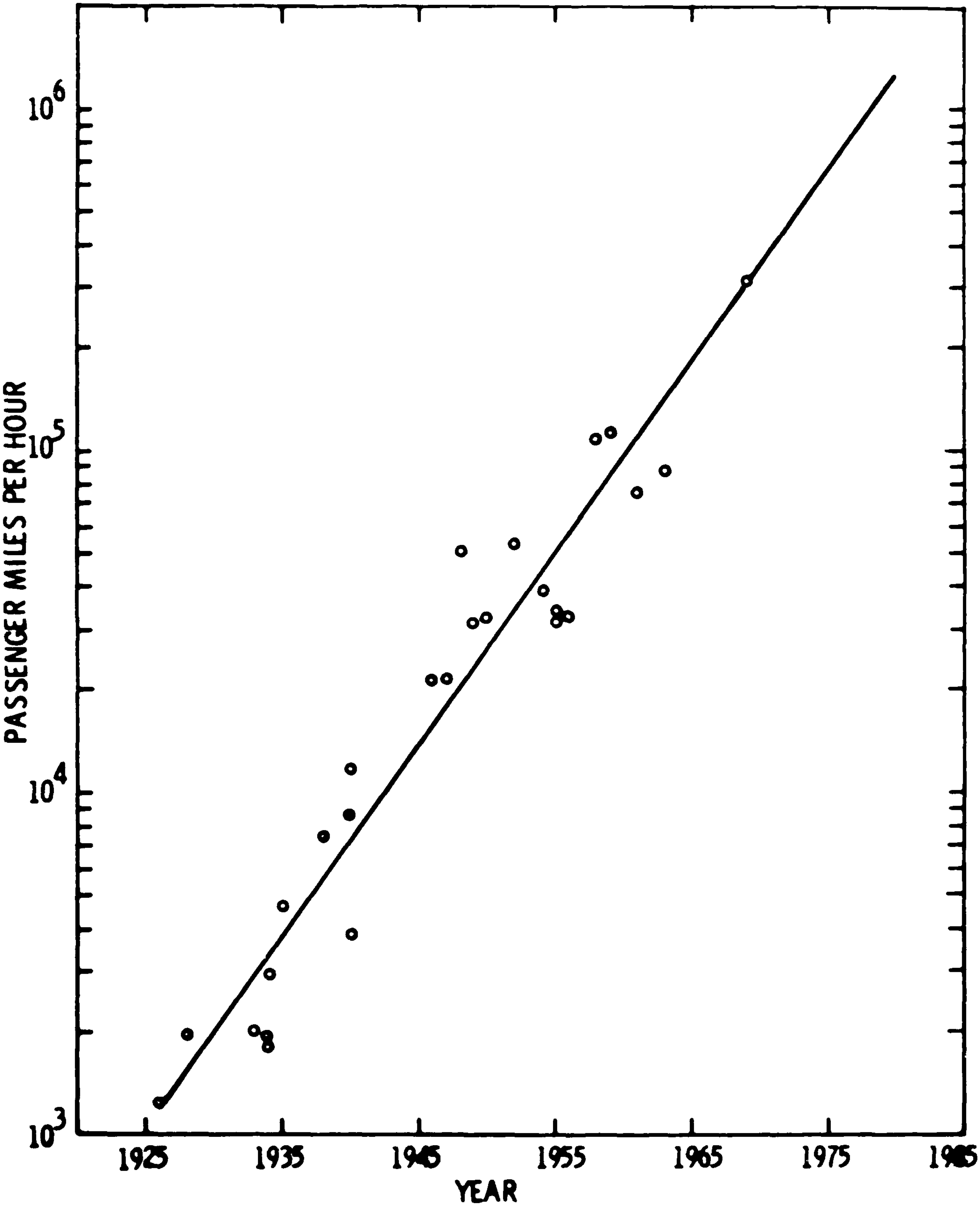
J. W. Rigney
1976

DR. JOSEPH P. MARTINO

Technological Forecasting With Confidence

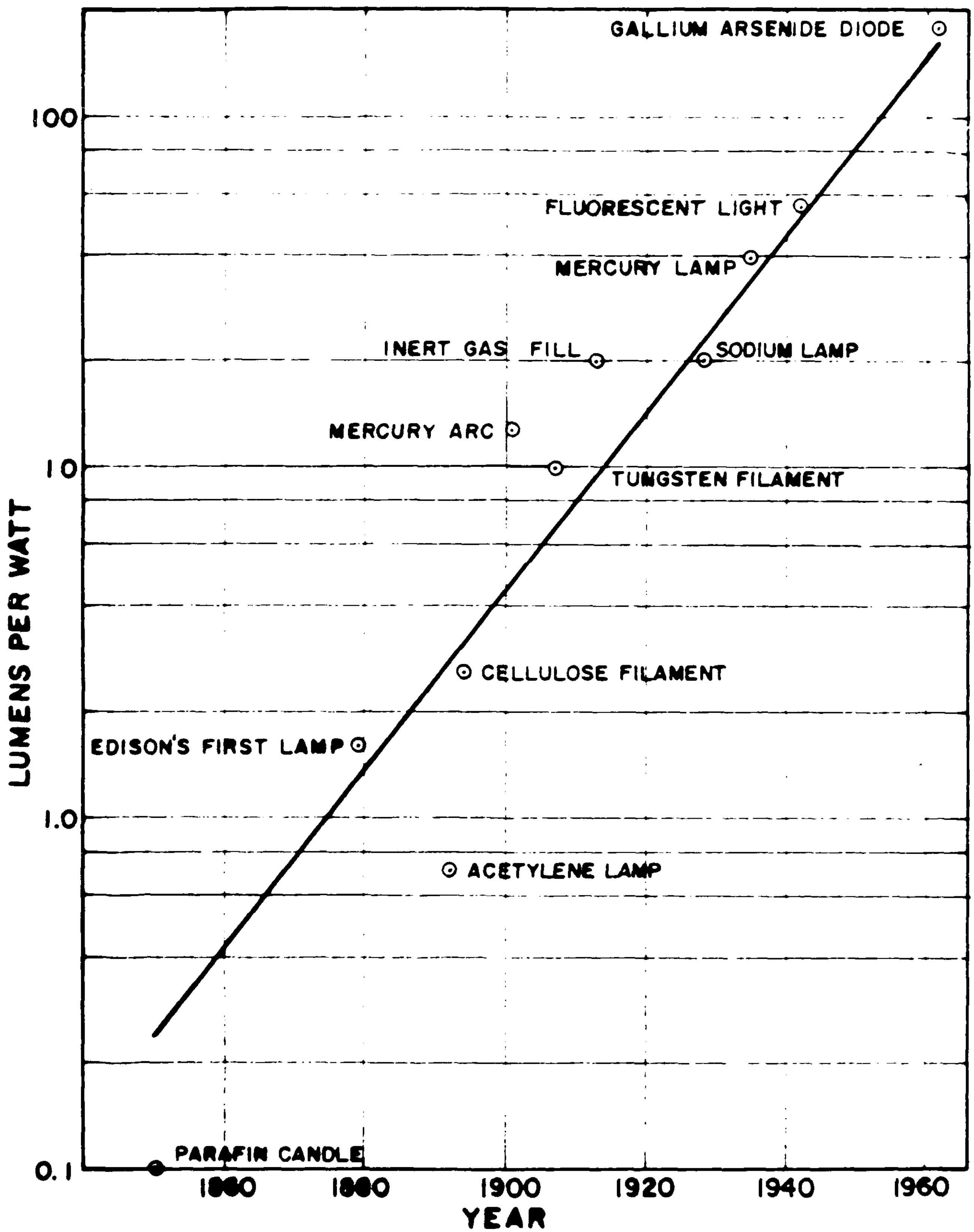

TOP SPEED—MPH
1000
100
10
1900
1910
1920
1930
1940
1950
1960
YEAR

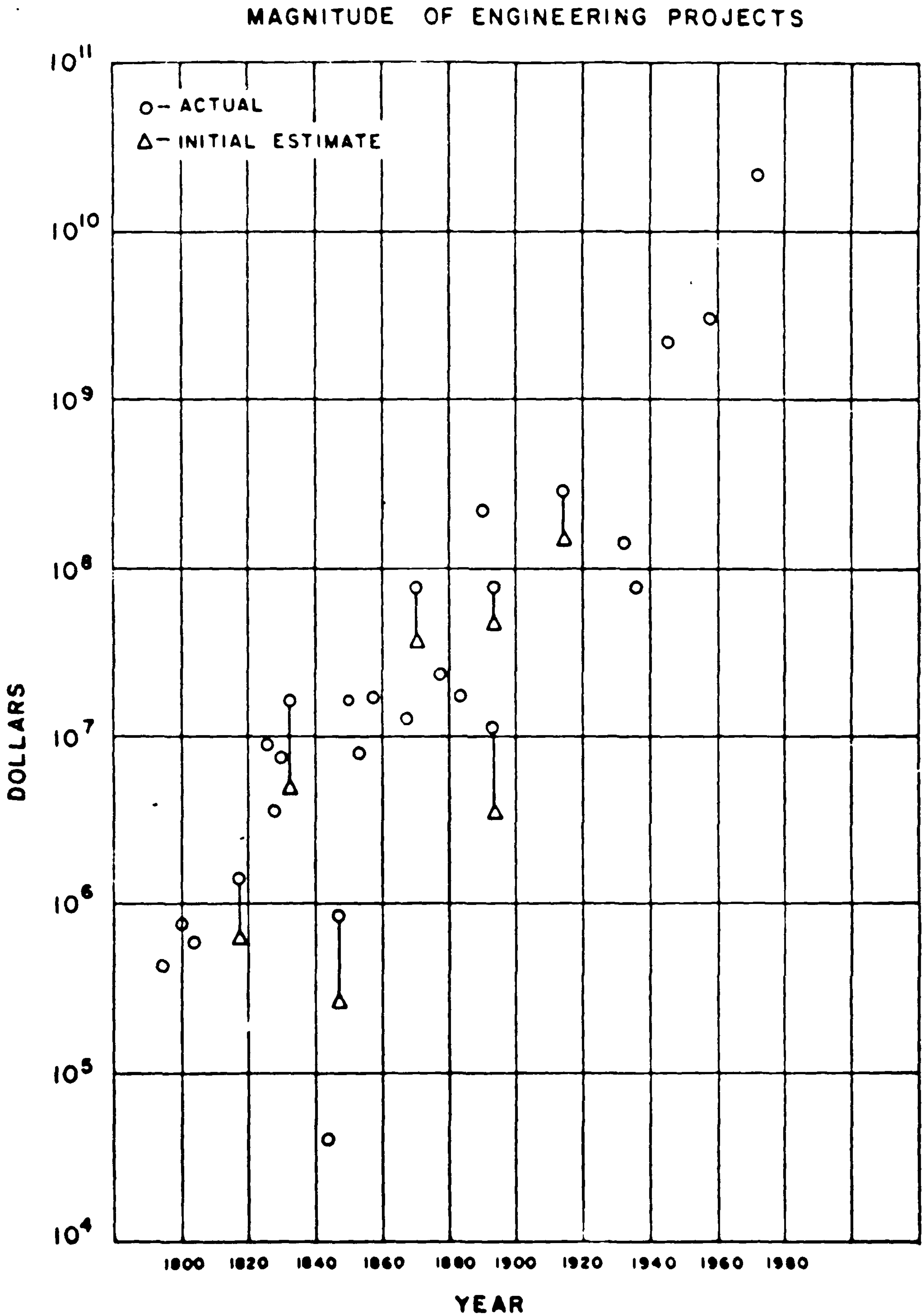

F-111
F-4
POUNDS
10^5
10^4
10^3
1910
1920
1930
1940
1950
1960
1970
YEAR



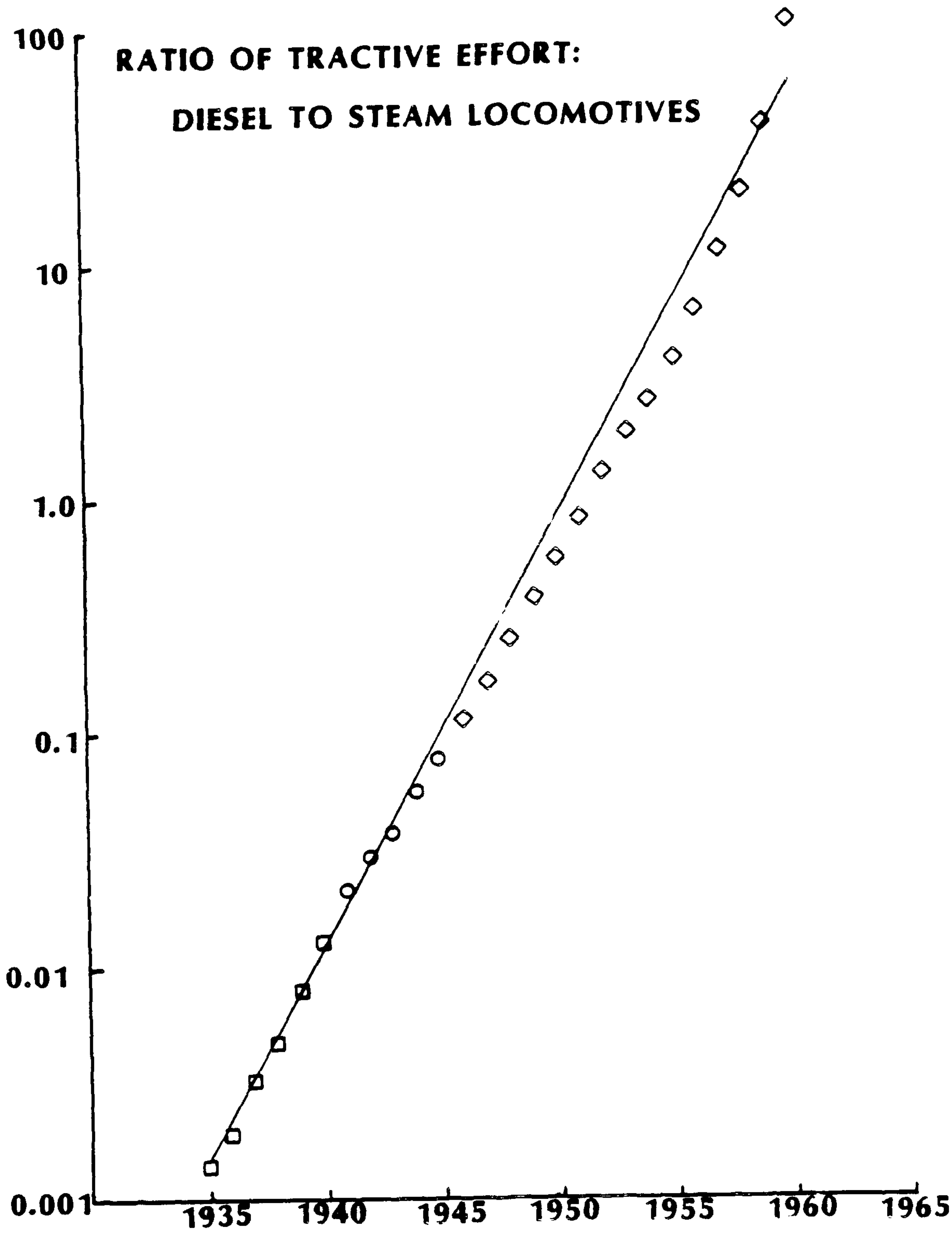
PASSENGER MILES PER HOUR
10^6
10^5
10^4
10^3
1925
1935
1945
1955
1965
1975
1985
YEAR

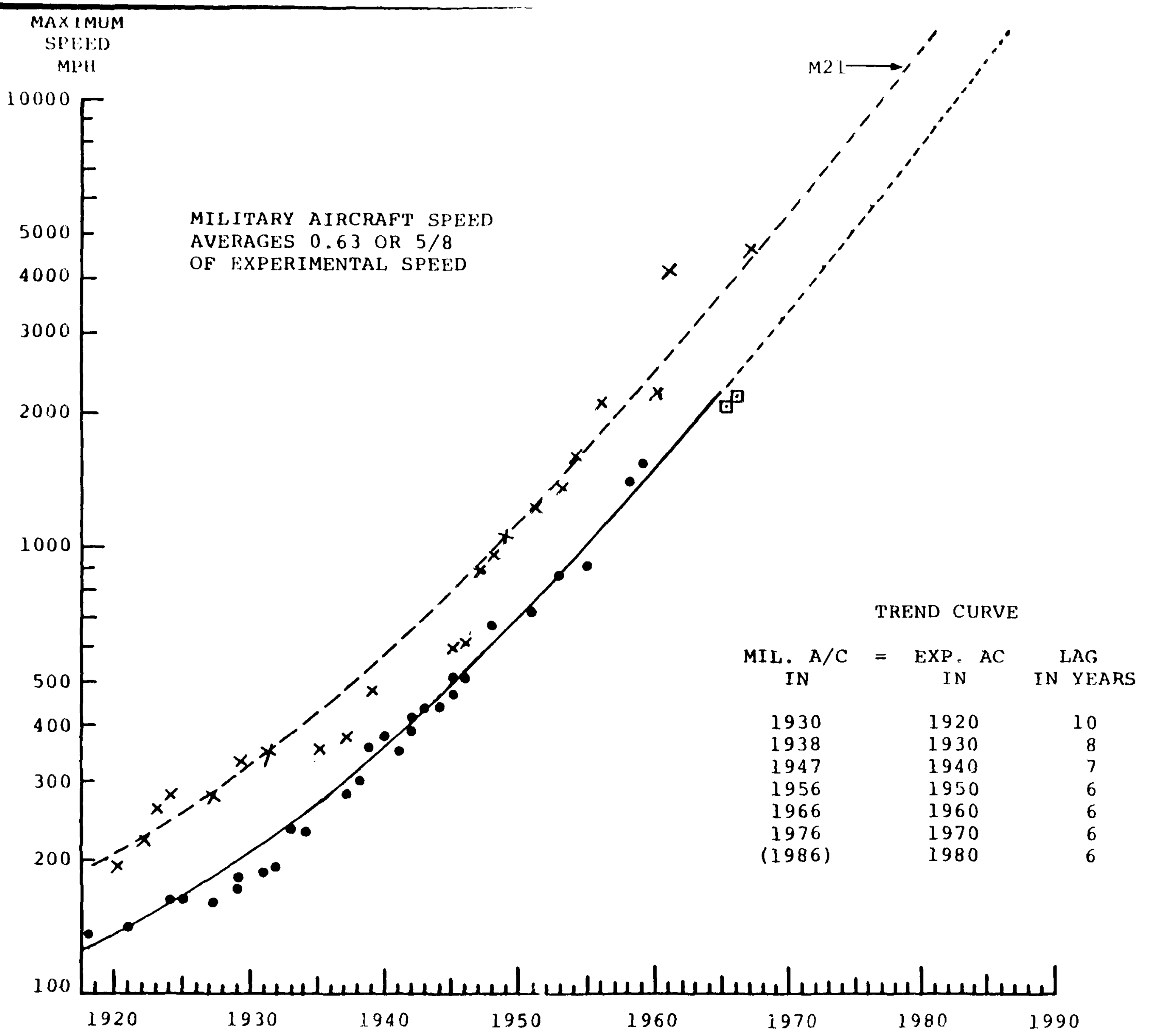
366


GALLIUM ARSENIDE DIODE
FLUORESCENT LIGHT
MERCURY LAMP
INERT GAS FILL
SODIUM LAMP
MERCURY ARC
TUNGSTEN FILAMENT
CELLULOSE FILAMENT
EDISON'S FIRST LAMP
ACETYLENE LAMP
PARAFIN CANDLE
LUMENS PER WATT
100
10
1.0
0.1
1860
1880
1900
1920
1940
1960
YEAR



MAGNITUDE OF ENGINEERING PROJECTS
O– ACTUAL
Δ– INITIAL ESTIMATE
DOLLARS
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
1800
1820
1840
1860
1880
1900
1920
1940
1960
1980
YEAR


RATIO OF TRACTIVE EFFORT:
DIESEL TO STEAM LOCOMOTIVES
100
10
1.0
0.1
0.01
0.001
1935
1940
1945
1950
1955
1960
1965



MIL. A/C IN	=	EXP. AC IN	LAG IN YEARS
1930		1920	10
1938		1930	8
1947		1940	7
1956		1950	6
1966		1960	6
1976		1970	6
(1986)		1980	6

HISTORY OF ATOMIC ENERGY

1905	MASS-ENERGY EQUIVALENCE
1906	ISOTOPES OF RADIOACTIVE ELEMENTS
1911	ATOMIC STRUCTURE (RUTHERFORD)
1913	ISOTOPES OF NONRADIOACTIVE ELEMENTS (THOMSON)
1919	EJECTION OF PROTONS FROM NITROGEN (RUTHERFORD)
1919	MASS SPECTROSCOPY (ASTON)
1920s	MASS DEFECT (ASTON)
1932	DISCOVERY OF THE NEUTRON (CHADWICK)
1938	FISSION OF URANIUM NUCLEUS
1939	CHAIN REACTION HYPOTHESIZED (FERMI)
1942	CHAIN REACTION DEMONSTRATED
1945	NUCLEAR WEAPONS
1956	FIRST COMMERCIAL ATOMIC POWER (CALDER HALL)

MAJOR EVENTS IN THE HISTORY OF THE JET ENGINE

1910 COANDA - JET EXHAUST, PISTON-DRIVEN COMPRESSOR

1913 LORIN - COMPRESSION BY RAM EFFECT (RAM-JET)

1921 GUILLAUME PATENT ON JET ENGINE WITH TURBINE-DRIVEN COMPRESSOR

1923 BUCKINGHAM REPORT TO US ARMY ON JET ENGINE EFFICIENCY

1926 GRIFFITH - TURBINE-DRIVEN PROPELLER (TURBOPROP)

1931 AIRCRAFT TURBOSUPERCHARGERS
COMPRESSION RATIO 2:1
EFFICIENCY 62%

1935 TURBOSUPERCHARGER
COMPRESSION RATIO 2.5:1
EFFICIENCY 65%

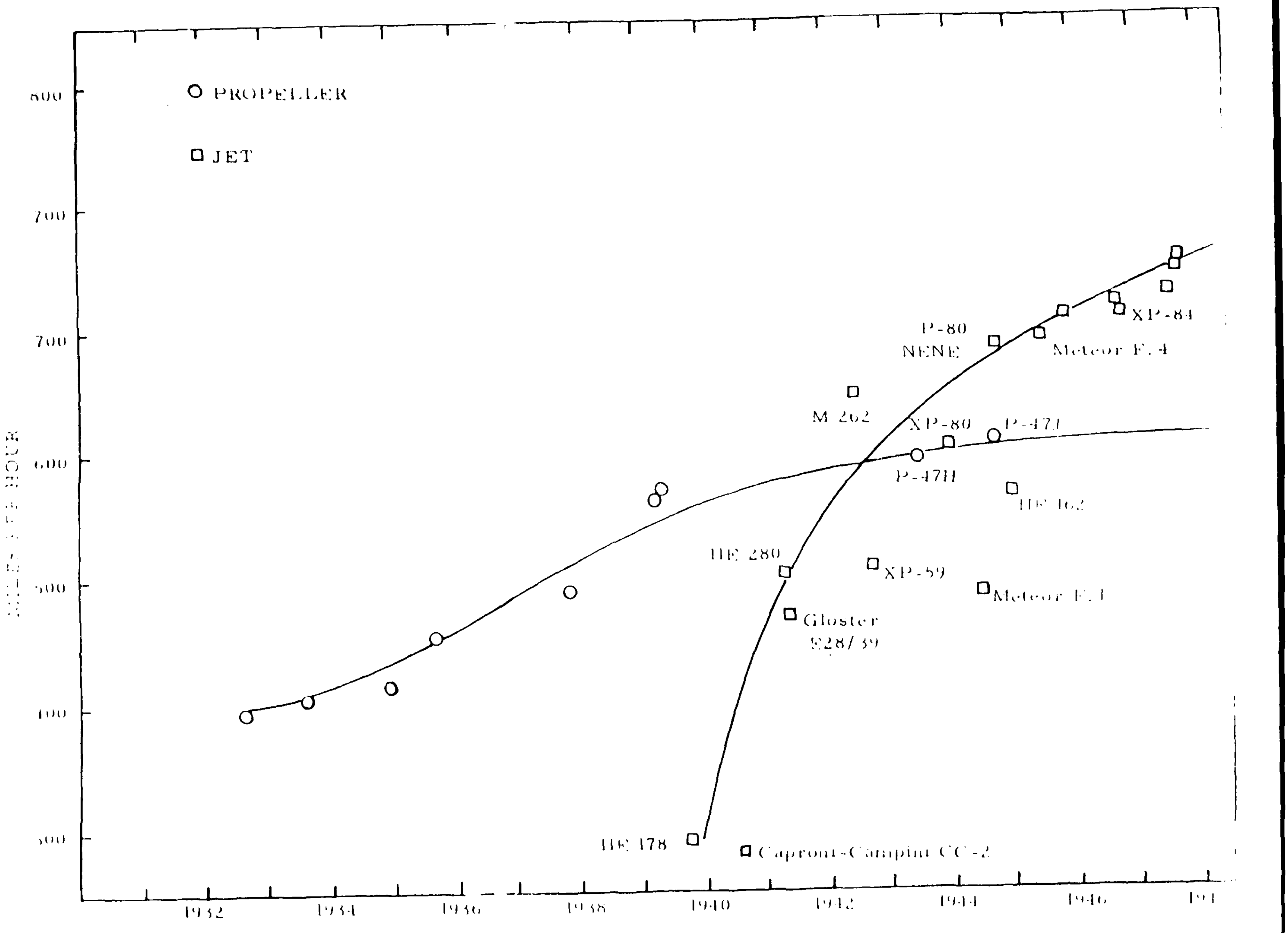
1935 VON OHAIN PATENT ON JET ENGINE WITH TURBINE-DRIVEN COMPRESSOR

1939 HE-178 JET FLIES WITH VON OHAIN ENGINE IN GERMANY

1940 CAPRONI-CAMPINI CC-2 JET FLIES IN ITALY WITH COANDA-TYPE ENGINE

1941 GLOSTER E28/39 JET FLIES IN ENGLAND WITH WHITTLE ENGINE

1942 XP-59 JET FLIES IN US WITH GE ENGINE



PROPELLER
JET
800
700
700
600
500
400
300
1932
1934
1936
1938
1940
1942
1944
1946
P-80
NENE
Meteor F.4
XP-84
M 262
XP-80
P-47J
P-47H
HE 162
HE 280
XP-59
Meteor F.1
Gloster
E28/39
HE 178
Caproni-Campini CC-2

J. E. LILIENFELD 1,745,175

METHOD AND APPARATUS FOR CONTROLLING ELECTRIC CURRENTS

Filed Oct. 8, 1926

Fig. 1.

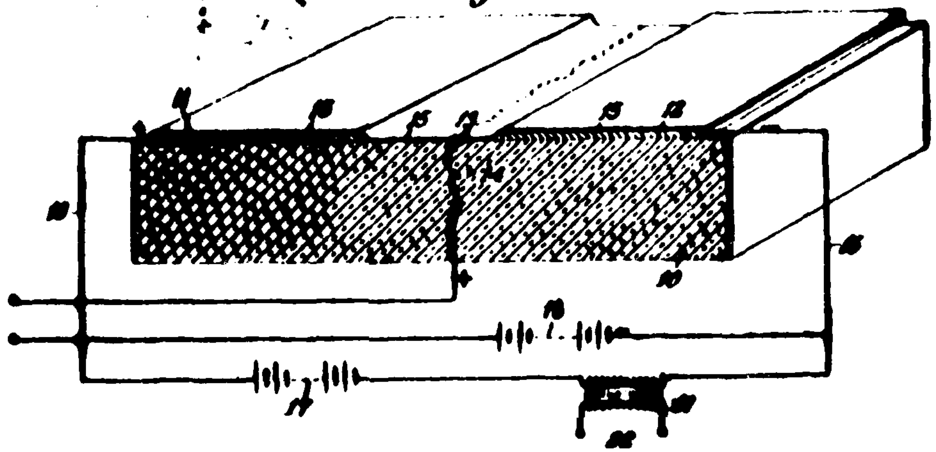
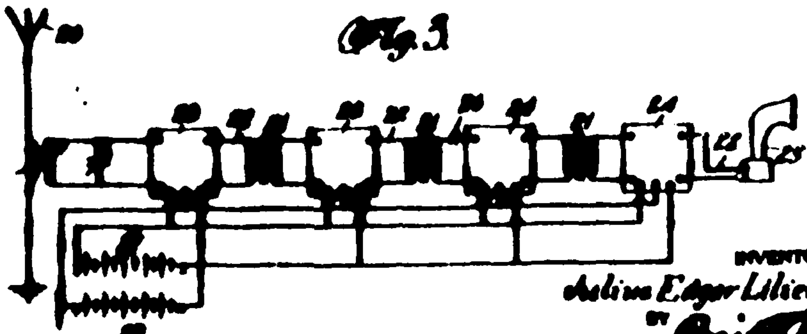


Fig. 2.

Fig. 3.



INVENTOR
Julius Edgar Lilienfeld
BY
ATTORNEY

374

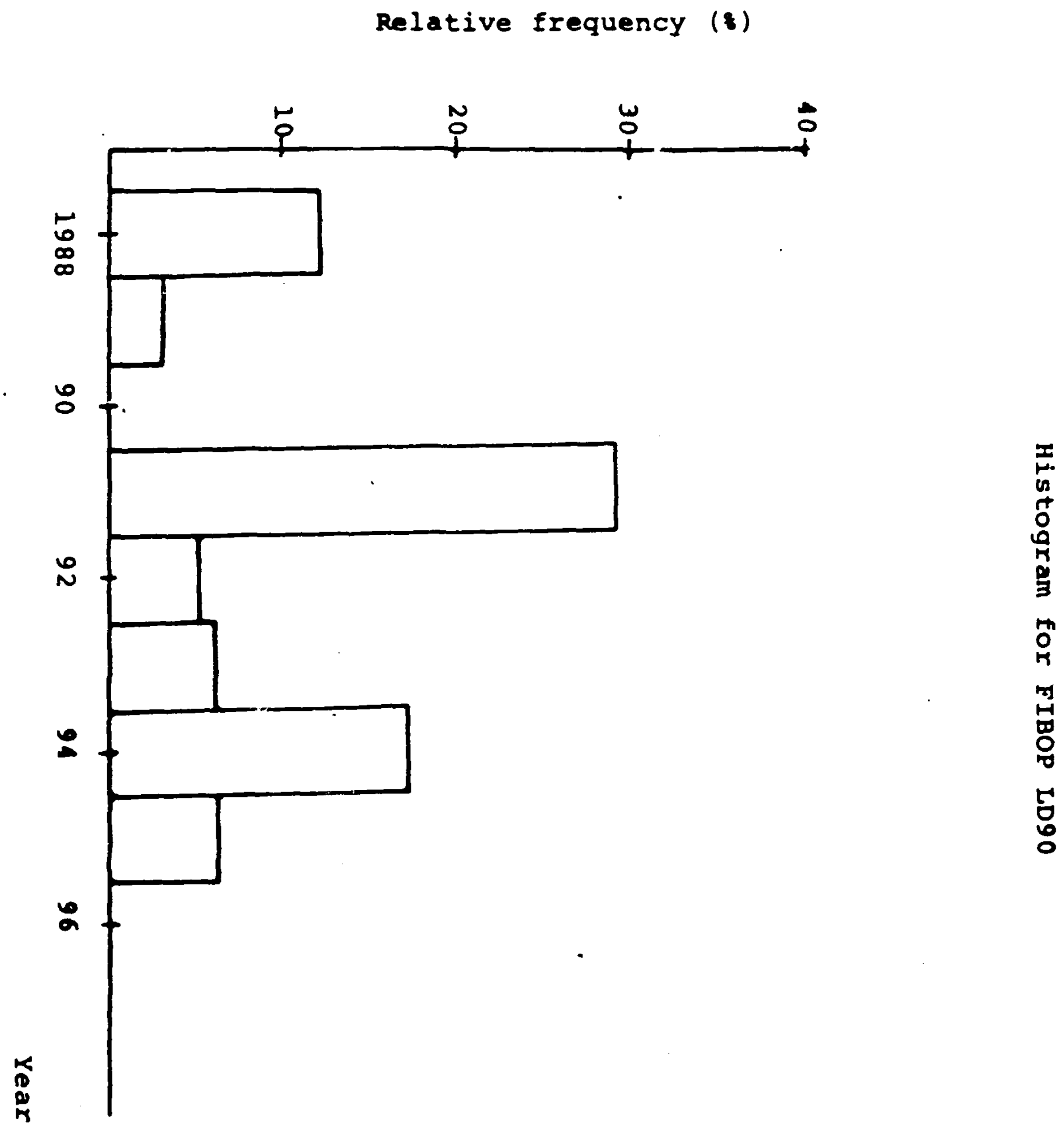


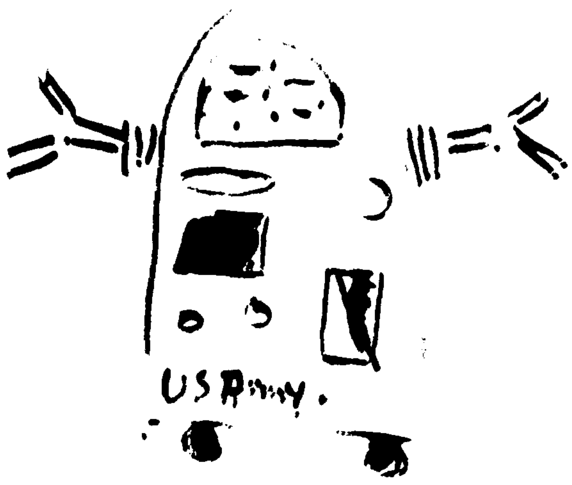
Figure 10. Distribution of Years in Which Fiber Optics Carry 90% of Long Distance Calls (From 100 Simulations)

Work Group I:

PREDOMINANT USE OF COMBAT ROBOTICS

COMBAT ROBOTICS

- McAlear
- Pangallo
- Stewart
- Finkelstein
- Holz



Robots need not "look like" the manned systems they are designed to replace!

ASSUMPTIONS:

- Robots (by some time in the future) will carry out those tasks currently performed by humans.
- On the future battlefeild, humans will not be present but will "monitor" robots.
- Intelligent interface will characterize the interface between human & robot

Scenarios for the US Army in 2010 +

- Hi-lethality battlefield in Western Europe will provide ideal ground for robots to engage conventional force
- Robots could be effectively used in performance of lower intensity (e.g. guerilla warfare, surveillance, "dull") tasks.
- Increases in robots could lead to reduction/elimination of today's ground combat soldiers & support soldiers.

Prerequisites for Robotics Fielding:

- fielding of "smart" robots will require a concerted effort across disciplines (engineering; mechanics; physics; computer sciences; beh. sciences) & a critical mass of $.

- Willingness of current "leadership" (civ. & mil.) to consider alternative structures / manning / grade structure / etc. etc

- R&D in education & training specific to Army and robotics will probably flow from
  - .. surveillance systems (i.e. RPA's)
  - .. artillery
  - .. armor
  - .. ordanance
  - .. "grunt"

- Training of personnel to operate/maintain robots may require specific skills/capabilities of entering personnel – costs of recruiting such individuals could equal or exceed current & projected "total force" costs.

Education & Training R&D Issues:

. \$
.. Technology
.. Training applications for NDI (off-the-shelf)
.. Training Trainers

. Organizational Concerns
.. Architecture
.. Personnel Types /# /grades
.. Relationship to other orgs.

. Tech. Cost. & Reliability

. Vested Interests
.. Ψ
.. econ
.. social

Implications of Robotics Movement:

.. new skill categories

.. fewer personnel

.. different educational/aptitude requirements

.. changes in organizational structure of force.

Robotics R & D -

Early: 1988-1995:

- Training of human operators
  - diagnostics
  - maintenance

Mid-term: 1996-2000:

- Robotic Based Training/Instruction
  - the "DI as a robot/expert system

Long range: 2005 >:

- Robot/human exercises/war games
- Robot/Robot Training

Psychological Research & Robotics

.. Human dimension → reluctance
→ anthropomorphism

.. Pattern Recognition

.. Perception

.. Design of Expert Systems

.. Multi-Disciplinary Research is needed

— real challenge —

I.

"Opportunities"

- establish a central location (agency) to serve as coordinator for robotics R&D.
- ID a "spokesperson" for resources – DOD –
- "Classified" vs. open
- Seek linkages in private sector / other Govt. agencies (Labor; EPA &; Medical Community)
- Educate leadership

Vulnerabilities:

.. EW

.. Nuc bar

.. "Human Interference"

.. Countermeasures not acceptable?

.. Should robotics R & D be carried out by the military?

.. Moral/ethical question: future of man?

388

Work Group II:

HUMAN SOLDIER AUGMENTED BY AUTOMATION

INDIVIDUAL

AUGMENTATION

SENSORY ENHANCEMENT
AVAILABLE INFORMATION
DECISION AIDING
MOBILITY
COMMUNICATION

ENVIRONMENT CHANGE

PHYSICAL
PSYCHOLOGICAL
NBC

SOLDIER CHARACTERISTICS

ENDURANCE

MENTAL
PHYSICAL

FLEXIBILITY

INDEPENDENT
FLUID GROUPS

TECHNICAL COMPETENCE

MULTIPLE EQUIPMENTS
MULTIPLE DOCTRINE

A. IMPROVED UTILIZATION OF EXISTING TECHNOLOGIES

1. DEVELOPMENT OF EDUC. SOFTWARE, INCLUDING GRAPHICS.
2. ADVANCED SIMULATIONS
3. TEAM TRAINING FOR COHESION
4. STRESS MANAGEMENT

B. EMERGING TECHNOLOGIES

1. BRAIN CHEMISTRY

2. COGNITION
   a. PERCEPTION
   b. LEARNING
   c. MEMORY
   d. ATTENTION
   e. NEURAL PHYSIOLOGY

3. STATE SPECIFIC LEARNING

4. MAN/MACHINE EMPATHY

5. INFORMATION ACQUISITION AND PROCESSING MECHANISMS

Work Group III:

SOLDIER WITH ENHANCED HUMAN CAPABILITIES

TARGET CAPABILITY

A. INFORMATION PROCESSING

B. CONCENTRATION

C. SUSTAINED PERFORMANCE

D. STRESS/PAIN MANAGEMENT

CONSTRUCT	BIOLOGICAL BASIS
A. ASSOCIATION (LEARNING/MEMORY)	A. Cerebral Cortex
B. Attention	B. Reticular System
C. Arousal + Attention	C. Limbic System
D. Analgesia	D. Spinal Chord/Cortex

ENDORPHINS

- CONCENTRATIONS
- SPECIALIZED RECEPTORS

Active Man/Machine Effects

Deterioration of performance

Own

Opponents

Enhancement of performance

Resonant man/machine

Active Man/Man Effects

Paranormal communication

Anomalous info. acquisition

Enhanced team performance

General Intuitive Capabilities

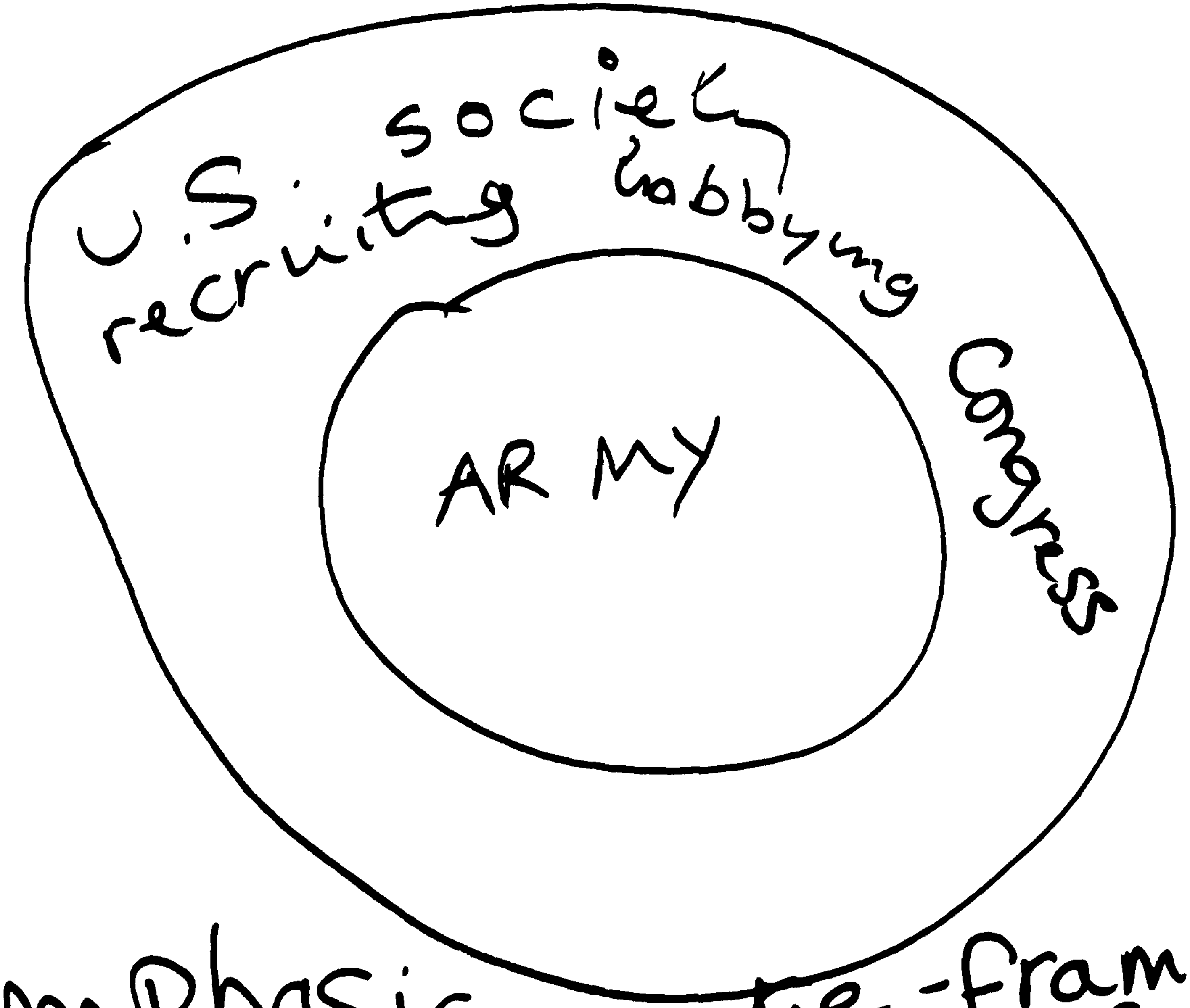
Supplement analytical & technological sophistication

Selection

Education

Facilitation

MINORITY VIEW - HENDERSON



emphasis on re-framing problem

7

<u>most</u> single-mission insts
same problem.

- nation-states
- mncs
- R.C. church
- labor unions
- universities (corporate ed.)

systemic problems /crises

- restructuring usually occurs as a large crisis
-